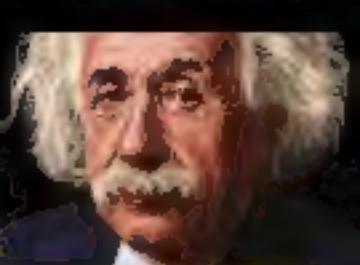


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# 50

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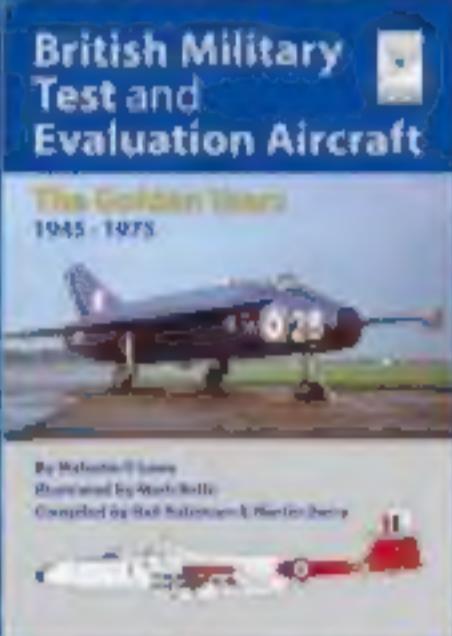
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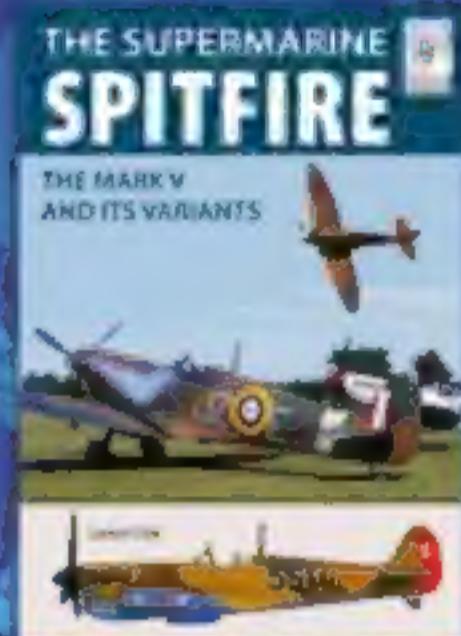
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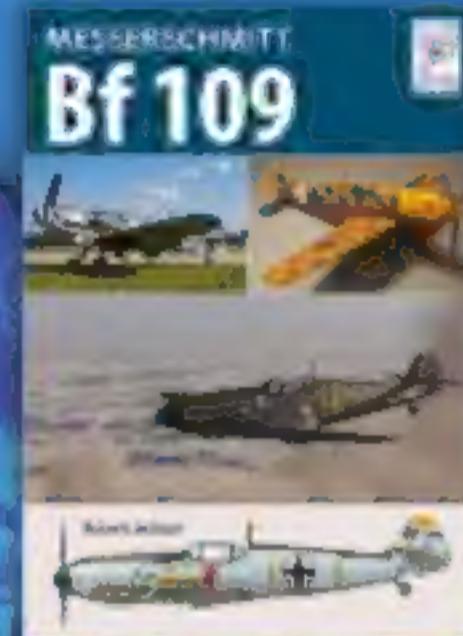
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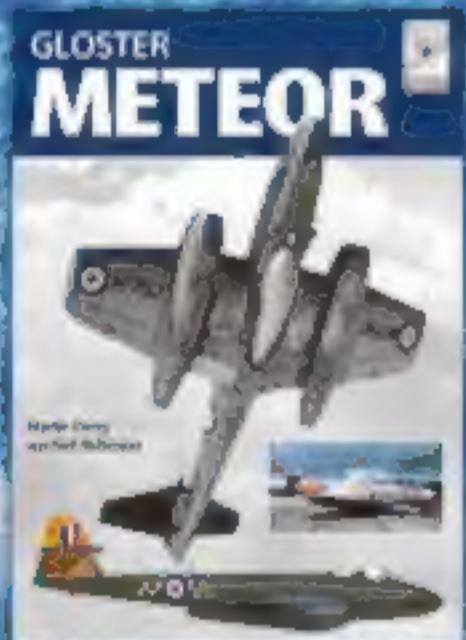
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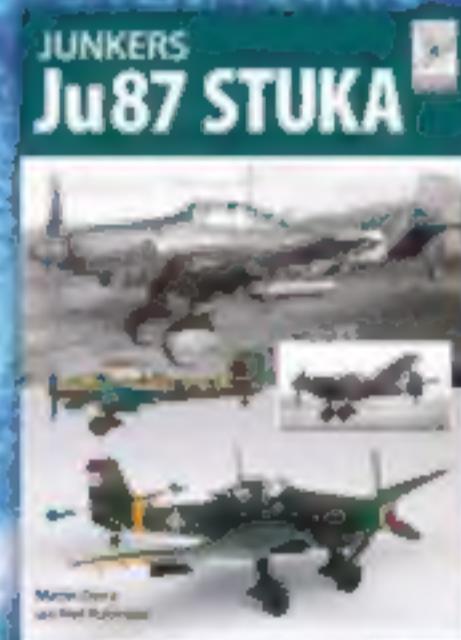
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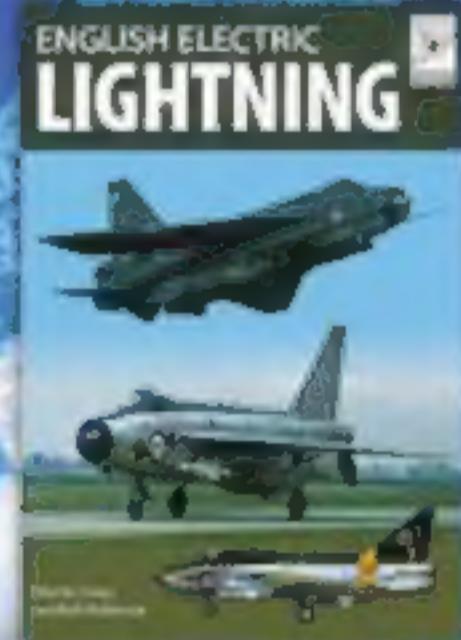
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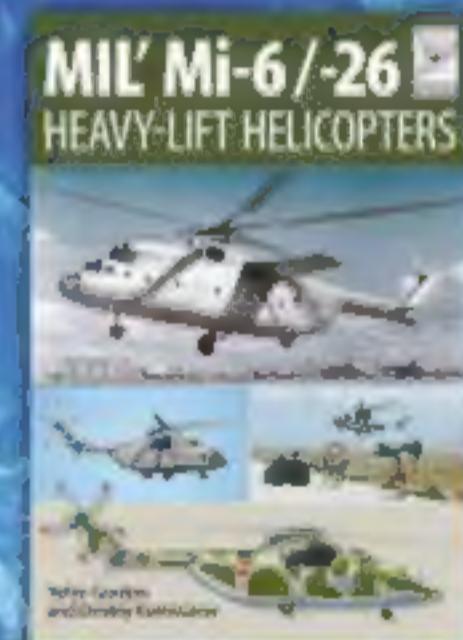
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# WELCOME

The magazine that feeds minds!



**"It will have the same impact as electricity and steam had in the previous industry revolutions"**

How 5G will supercharge your life, page 22

## Meet the team...



**James**  
Production Editor  
On page 78 we take a look at some of the colossal creepy-crawlies that once roamed the Earth – including a terrifying giant scorpion.



**Scott**  
Staff Writer  
Is a bird brain so different from that of a rabbit? We discover what's between the eyes of the world's animals on page 70.



**Baljeet**  
Research Editor  
Will we ever really be able to travel back in time? Find out with our beginner's guide to time travel over on page 36.



**Duncan**  
Senior Art Editor  
See what early human habitats on Mars might look like on page 72 (hint – it's a lot nicer than what Mark Watney has in *The Martian*). Contactless cards are transforming the way we pay, but are they safe? Discover how NFC hands over your money through the air on page 34.



**Ailsa Harvey**  
Staff Writer  
Contactless cards are transforming the way we pay, but are they safe? Discover how NFC hands over your money through the air on page 34.



**Ben Biggs**

Editor

The scope of 5G's cellular networks is probably going to blow even the early adopters away. It goes way beyond simply streaming video faster on your mobile phone: this reliable

and super-quick technology is itself a technology enabler. When 5G rolls out, driverless cars will become ubiquitous, surgeons will be able to operate without being in the same room as the patient, advertisers will be able to put moving images on any surface. And your local school? 5G is coming to a classroom near you soon! Read more about how 5G works on page 22. Enjoy the issue!



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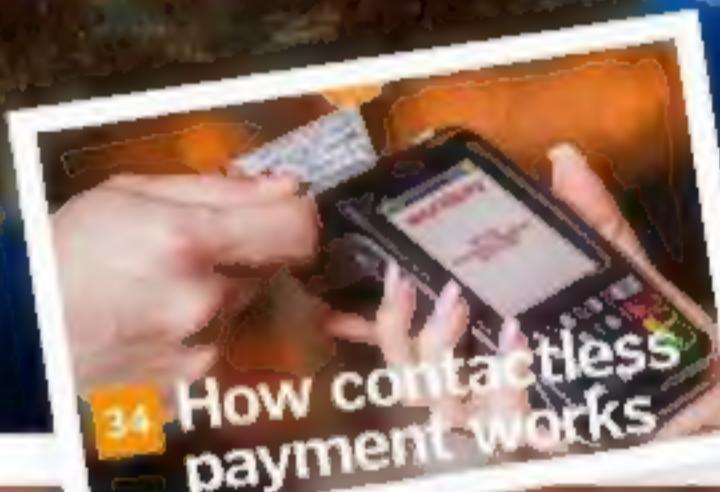
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# THE FUTURE IS HERE

# 5G



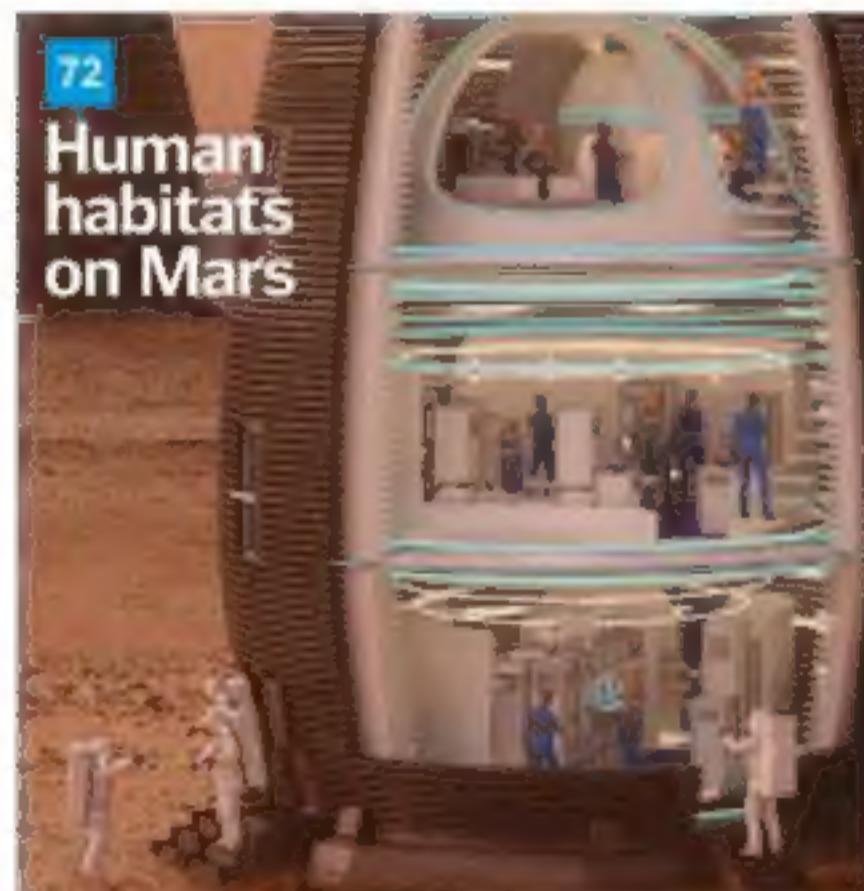
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## MEET THIS ISSUE'S EXPERTS...



### James Horton

Former HIW member James is a biochemist and biotechnologist. He is currently doing a PhD in machine learning and evolutionary theory.



### Jo Stass

Writer and editor Jo is particularly interested in the natural world and learning about the latest in technological innovations.



### Jodie Tyley

The former editor of HIW and All About History has tackled many topics in her career, from science fiction to science fact, and Henry VIII to honey badgers.



### Laura Mears

Biomedical scientist Laura escaped the lab to write about science and is now working towards her PhD in computational evolution.



### Stephen Ashby

Stephen is a writer and editor with video games and computer tech expertise. He is endlessly intrigued by Earth science.



### Steve Wright

Steve has worked as an editor on many publications. He particularly enjoys history feature writing and regularly writes literature and film reviews.



### Amy Grisdale

Volunteer animal worker Amy has an enormous breadth of experience on animal and conservation projects. She specialises in environmental topics.



### Tom Lean

Tom is a historian of science at the British Library, working on oral history projects. His first book, *Electronic Dreams*, was published in 2016.

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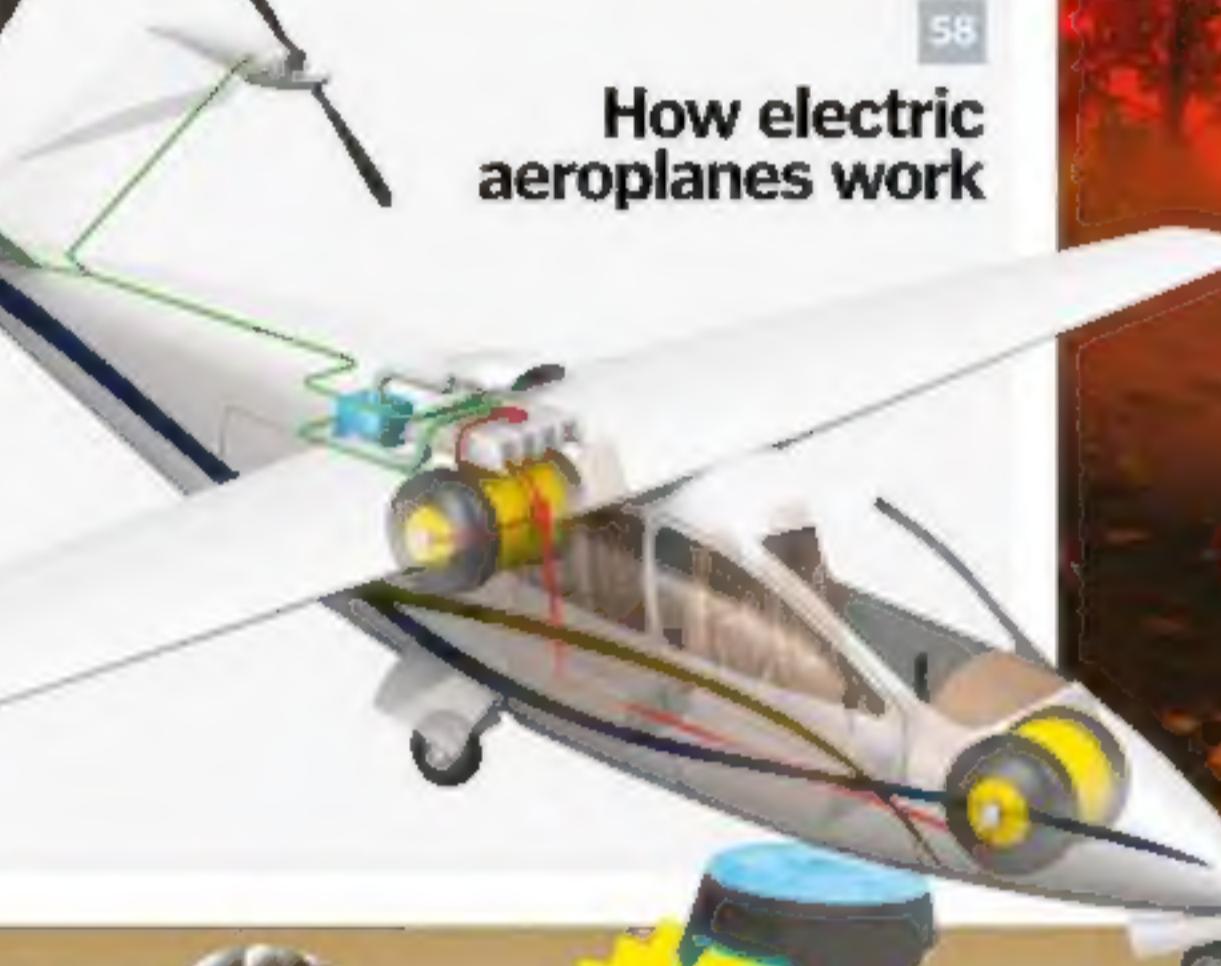
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Exploring the giant moon of Saturn



### Victoria Williams

Evolutionary biologist and keen writer Vicki is fascinated by the natural world and is happiest when she's outdoors.



### Lee Cavendish

Avid stargazer Lee writes for our sister magazine, **All About Space**, has a degree in observational astronomy and loves a bit of technology writing, too.



### Dr Andrew May

Andrew has a PhD in astrophysics and 30 years in public and private industry. He enjoys space writing and has written several books.



### Jack Parsons

A self-confessed technophile, Jack has a keen interest in gadgets and wearable tech, but also loves to write about projects with much grander ambitions.



### Jonny O'Callaghan

With a background in astrophysics, former **HiW** and **All About Space** writer Jonny enjoys delving into the wonders of space and space missions.



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## Dying alga's green gift

This is an euglenoid alga, a tiny water-dwelling organism with a whip-like appendage that it uses to move through the water. The lake this one was taken from in Vietnam was heavily polluted. In this image, shot using a scanning electron microscope (SEM) and digitally coloured, the alga is dying, releasing the photosynthetic chloroplasts that produce its energy. It was taken by Steve Gschmeissner for The Royal Photographic Society's science photography competition. You can find out about this year's Science Photographer of the Year competition at [rps.org/spoty](http://rps.org/spoty).

## Air traffic control drone

Above Reno, Nevada, a drone monitors the airspace as a part of NASA's new unmanned air traffic management system. It's the first of two drone test flights aiming to make the airways safe as a new wave of low-altitude, unmanned operations take off. As well as directing low-altitude urban airspaces and enforcing flight corridors, NASA's system will provide weather warnings. It will manage drones, gliders, helicopters and other aircraft flying below 120 metres.





**Big cat of  
the reptile world**





## New form of gold created

Words by Yasemin Saplakoglu

**U**nder extreme conditions gold rearranges its atoms and forms a previously unknown structure. When the pressures are pushed to the equivalent of those at the centre of the Earth, the gold gets even weirdier.

This finding comes from a new study in which researchers from the Lawrence Livermore National Laboratory (LLNL) and the Carnegie Institution for Science practised some 21st-century alchemy at the Argonne National Laboratory in Illinois, US. Using a high-energy laser, researchers heated gold to extreme temperatures and compressed it to pressures as high as those found at the Earth's centre.

More specifically, they put a little piece of plastic in front of a chunk of gold and shot a high-energy laser through the plastic, which "basically causes an explosion that sends plastic one way and

shockwaves in the opposite direction," said lead author Richard Briggs, a postdoctoral scientist at LLNL. Those shockwaves hit the gold and caused it to compress and heat up extremely quickly, within nanoseconds.

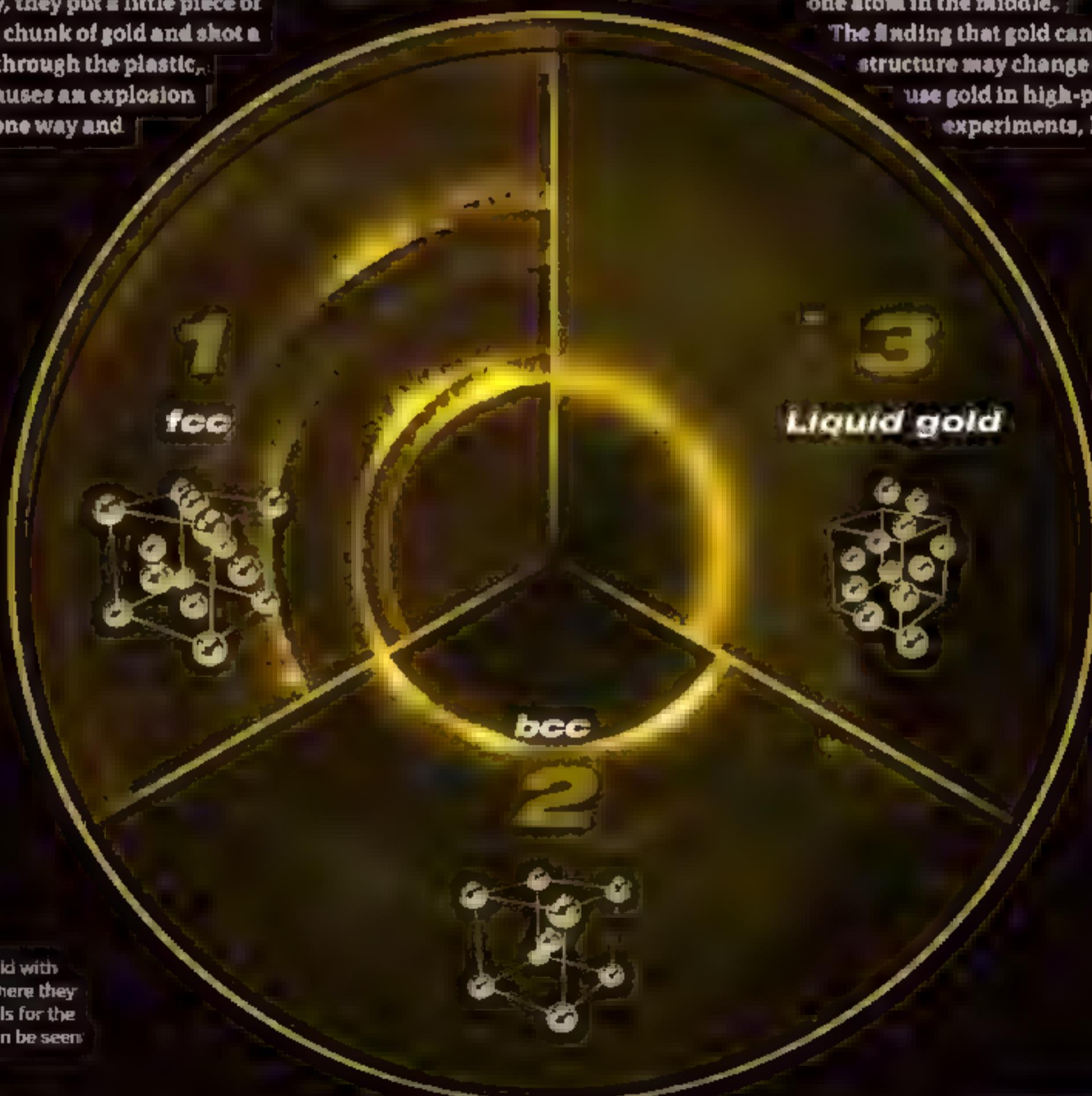
They then hit the gold with x-rays and detected where the x-rays bounced off in order to figure out its structure. It's "the first time that we've ever been able to reach such high-pressure and high-temperature conditions and look at them at the same time using x-rays," Briggs told *Live Science*.

What they saw was "certainly a surprise". Gold usually forms a crystalline structure that scientists call face-centred cubic (fcc). Imagine a cube like a die. Atoms would sit on

each corner and each face, Briggs said. But most experiments conducted on gold have involved compressing it slowly and at room temperature, he added. Because it so loyally forms this face-centred cubic structure, gold has been used as a kind of 'standard' in high-pressure experiments to calculate pressure, Briggs explained.

When the team rapidly compressed the gold at high temperatures, it formed what's called the body-centred cubic (bcc) structure. This more open structure packs atoms into a space in a less efficient way, so the gold doesn't prefer to be in this form. If you were to imagine the die again, it would be as if atoms sat on each corner, with just one atom in the middle.

The finding that gold can form this structure may change how scientists use gold in high-pressure experiments, Briggs said.



Researchers hit the gold with x-rays and detected where they bounced off (the signals for the different structures can be seen on this image)

Made from Chernobyl aquifer water and radioactive rye, Atomik vodka is the first consumer product to come out of the Chernobyl exclusion zone in 33 years

ATOMIK

ATOMIK  
VODKA  
IN CHORNObYl

ATOMIK  
VODKA  
IN CHORNObYl

## PLANET EARTH

## New vodka made from radioactive grain

Words by Brandon Specktor

Thrill seekers visiting the ruins of the Chernobyl nuclear power plant in Ukraine may soon be able to take a piece of the site's radioactive history home with them – in their livers. A team of scientists from the UK and Ukraine have just produced the first bottle of what they're calling Atomik vodka, artisanal spirits made from water and grain harvested in the reactor's once-forbidden exclusion zone.

Though the 2,600-square-kilometre zone surrounding the plant was initially declared uninhabitable by humans for 24,000 years following the 1986 meltdown, the makers of Atomik assured BBC News reporters that their product is no more radioactive than any other liquor on the market.

Part of that is because much of the exclusion zone is not as dangerous as it was feared to be 33 years ago. Some radiation hotspots – such as the Red Forest, where much of the radioactive material from the reactor spilled – remain off-limits. However, for the most part, the risk of radiation contamination in much of the exclusion zone is now considered 'negligible' by the Ukrainian government, which reopened the zone to tourism nearly a decade ago.

According to Anders Møller, a biologist who's spent several weeks a year studying the exclusion zone for the past few decades, local crops are often contaminated with radiation and can cause "serious problems" if ingested.

Sure enough, the rye that the Atomik founders grew in the exclusion zone for their

"The rye that the Atomik founders grew in the exclusion zone for their vodka tested positive for radiation"

vodka tested positive for radiation. However, according to Atomik co-founder and University of Portsmouth professor Jim Smith, all traces of contamination disappear in the distillation process, during which the fermented liquid gets purified and water and other diluting substances are removed. "Any chemist will tell you, when you distil something, impurities stay in the waste product," Smith told the BBC. Radiation tests conducted by scientists at the University of Southampton confirmed the product to be as safe as any other hard liquor that's on sale.

Just one bottle of Atomik vodka exists at the moment, but the founders hope to cap at least 500 others by year's end and sell them to thirsty Chernobyl tourists.



## 'Piglet squid' spotted in deep sea dive

Words by Rafi Letzter

**M**arine scientists have released a stunning video of a strange critter, the piglet squid, floating along with its tentacles waving above its head, in the central Pacific Ocean near Palmyra Atoll.

Scientists spotted the squid about 1,385 metres below the ocean surface, while aboard the exploration vehicle (E/V) Nautilus. "What are you?" one of the voices in the video can be heard asking, as the small creature comes into view. "Is that a squid? I think it's a squid. It's like a bloated squid with tiny tentacles and a little hat that's waving around. And it looks like it's got a massive, inflated mantle cavity. I've never seen anything quite like this before."

That's an accurate description of the piglet squid, which is also known for its siphon that looks like the nose of a young pig. Piglet squids, like all cephalopods, have radically different bodies from animals that we're used to seeing on land. The piglet squid's unusual mantle-to-legs ratio is, in part, a consequence of how it moves through the water. According to Nautilus scientists, that mantle is filled with ammonia, which the squid uses to control its buoyancy.

PHOTOGRAPH BY

# Skywatching spider photobombs a meteor shower

Words by Meghan Bartels

**H**ow do you spot a shooting star? Well, you don't look for eight legs, that's for sure. But a NASA camera designed to photograph meteors spotted more than it bargained for during the Perseid meteor shower, when a curious spider stopped by.

The photograph was taken at Mt. Lemmon SkyCenter near Tucson, Arizona, on 5 August 2019. NASA maintains a network of 17 all-sky cameras, which capture black-and-white images of the entire sky using a fish-eye lens. The cameras are designed to spot fireballs, which are meteors that enter Earth's atmosphere in a streak brighter than Venus.

All-sky cameras regularly spot critters that are a little more terrestrial than meteors. NASA has previously published photos of a

bug, an owl and a small bird stopping by an all-sky camera. And this recent spider visit isn't the first time NASA has dealt with a photogenic arachnid: in 2007, a plumper spider crawled over a camera that was poised to watch the launch of the space shuttle Atlantis.

The Perseid meteor shower is traditionally the best one of the year, but this year the streakers are difficult to make out against the glow of the waxing moon. The Perseids peaked on 12 August this year, when skywatchers spotted between ten and 19 meteors per hour. The meteor shower continued through to 24 August. The Perseids happen when Earth plows through debris surrounding Comet Swift-Tuttle.



A NASA camera located near Tucson, Arizona, captured this image of a spider and a Perseid meteor.

## ANIMALS

# Staring at seagulls stops them stealing

Words by Mindy Weisberger

On the beach and on the boardwalk, gulls have a bad reputation for swooping down on unsuspecting people to steal their food. But researchers have discovered there's a simple way to deter these avian thieves: just stare at them.

Whereas a gull might be tempted to swipe your snack when you're distracted, they're less likely to do so when people are nearby, the researchers recently reported. Their experiments demonstrated that gulls were more cautious about approaching a tempting treat if there was a person nearby who was watching them closely. However, the scientists also found that far fewer of the birds than expected showed interest in investigating the food at all when being stared at.

On the beach and on the boardwalk, gulls have a bad reputation for swooping down on unsuspecting people to steal their food. But researchers have discovered there's a simple way to deter these avian thieves: just stare at them. Whereas a gull might be tempted to swipe your snack when you're distracted, they're less likely to do so when people are nearby, the researchers recently reported. Their experiments demonstrated that gulls were more cautious about approaching a tempting treat if there was a person nearby who was watching them closely. However, the scientists also found that far fewer of the birds than expected showed interest in investigating the food at all when being stared at.

gulls (*Larus argentatus*); these large, gregarious seabirds are found year-round in coastal regions around the UK, according to the Society for the Protection of Birds (RSPB). The researchers approached 74 herring gulls in a field in Cornwall, tempting them with a bag of fried potatoes. Most of the birds were curious or hungry enough to linger long enough for the scientists to place the bag on the ground a short distance away, waiting in position to see if a gull would approach. If a bird showed interest in the bag, the experimenter would either ignore the bird or stare at it intensely for 10 seconds. In the tests in which the researchers looked directly at the birds, 11 of the gulls wouldn't approach the bag at all, the researchers reported. In other tests in which the researchers looked away from the birds, 16 of the gulls wouldn't approach the bag at all, the researchers reported. There was also a lot of variation in the gulls' behaviour. Some gulls responded to the researcher's stare, while others appeared not to notice the researcher's stare. Overall, the gulls' behaviour was similar to that of humans: If humans were close to the birds,

Staring down a seagull  
can stop them from swooping  
down their advance  
towards our lunch.



## HEALTH

# Gene editing trial to treat blindness

Words by Rachael Rettner

The first study to test the gene-editing technology CRISPR inside the human body is about to get underway in the United States, according to news reports. The study plans to use CRISPR to treat an inherited eye disorder that causes blindness, the Associated Press reported.

People with this condition have a mutation in a gene that affects the function of the retina, the light-sensitive cells at the back of the eye that are essential for normal vision. The condition is a

form of Leber congenital amaurosis, one of the most common causes of childhood blindness that affects about two to three newborns out of every 100,000, according to the National Institutes of Health.

The treatment will correct the mutation using CRISPR, a tool that enables researchers to precisely edit DNA in a specific spot. Researchers will use an injection to deliver the treatment directly to the light-sensitive cells, according to a statement from Editas Medicine, the company

that is conducting the study, along with Allergan. The trial will enrol 18 patients, both children (ages three and up) and adults.

This study is different from the controversial research of a scientist in China who used CRISPR to edit the genomes of twin babies last year. In that case, the DNA of embryos were edited, and the gene alterations could be passed down to the next generation. In the new study, DNA edits made in the patients cannot be passed down to their offspring.



## HEALTH

## Organic apples found to be safer

N

If any creature could survive a crash-landing on the Moon, it would probably be a tardigrade



SPACE

## Lunar crash strands thousands of tiny bears on the Moon

Words by **Mindy Weisberger**

**W**hen you look up at the Moon, there may now be a few thousand water bears looking back at you. The Israeli spacecraft Beresheet crashed into the Moon during a failed landing attempt on 11 April. In doing so, it may have strewn the lunar surface with thousands of dehydrated tardigrades, also known as water bears.

Beresheet was a robotic lander. Although it didn't transport astronauts, it carried human DNA samples, along with the tardigrades and 30 million very small digitised pages of information about human society and culture. However, it's unknown if the archive - and the water bears - survived the impact when Beresheet crashed.

The tardigrades and the human DNA were late additions to the mission, added just a few weeks before Beresheet launched on 22 February. Much

like Cretaceous fossils locked in amber, the DNA samples and tardigrades were sealed in a resin layer protecting the DVD-sized lunar library, while thousands more tardigrades were poured onto the sticky tape that held the archive in place on the spacecraft.

But why send tardigrades to the Moon? Tardigrades are microscopic creatures that measure between 0.05 and 1.2 millimetres long. They have endearingly tubby bodies and eight legs tipped with tiny 'hands'. But tardigrades are

**"Tardigrades are as well known for their near-indestructibility as they are for their cuteness"**

as well known for their near-indestructibility as they are for their cuteness. Tardigrades can survive conditions that would be deadly to any other form of life, weathering temperature extremes of -200 degrees Celsius to more than 149 degrees Celsius. They can also survive exposure to the radiation and vacuum of space.

Another tardigrade superpower is their ability to dehydrate their bodies into a state known as a 'tun'. They retract their heads and legs, expel the water from their bodies and shrivel up into a tiny ball - and scientists have found that tardigrades can revive from this dehydrated state after ten years or more.

So whether any of these Beresheet tardigrades are biding their time in this state in a lunar impact crater, waiting until they can be resuscitated, only time will tell.



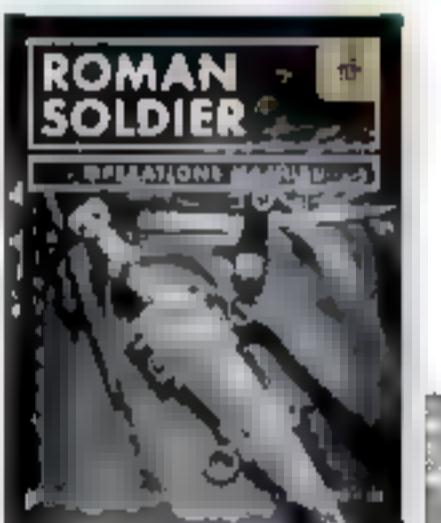
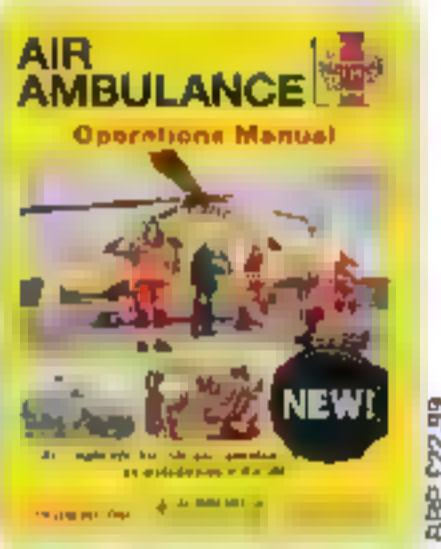
PLANET EARTH

## Satellite maps detailing Amazon deforestation

D



The Amazon rainforest is the largest area of rainforest on Earth, absorbing 2 billion tonnes of carbon dioxide every year and releasing 20 per cent of the Earth's oxygen.



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# WISHLIST

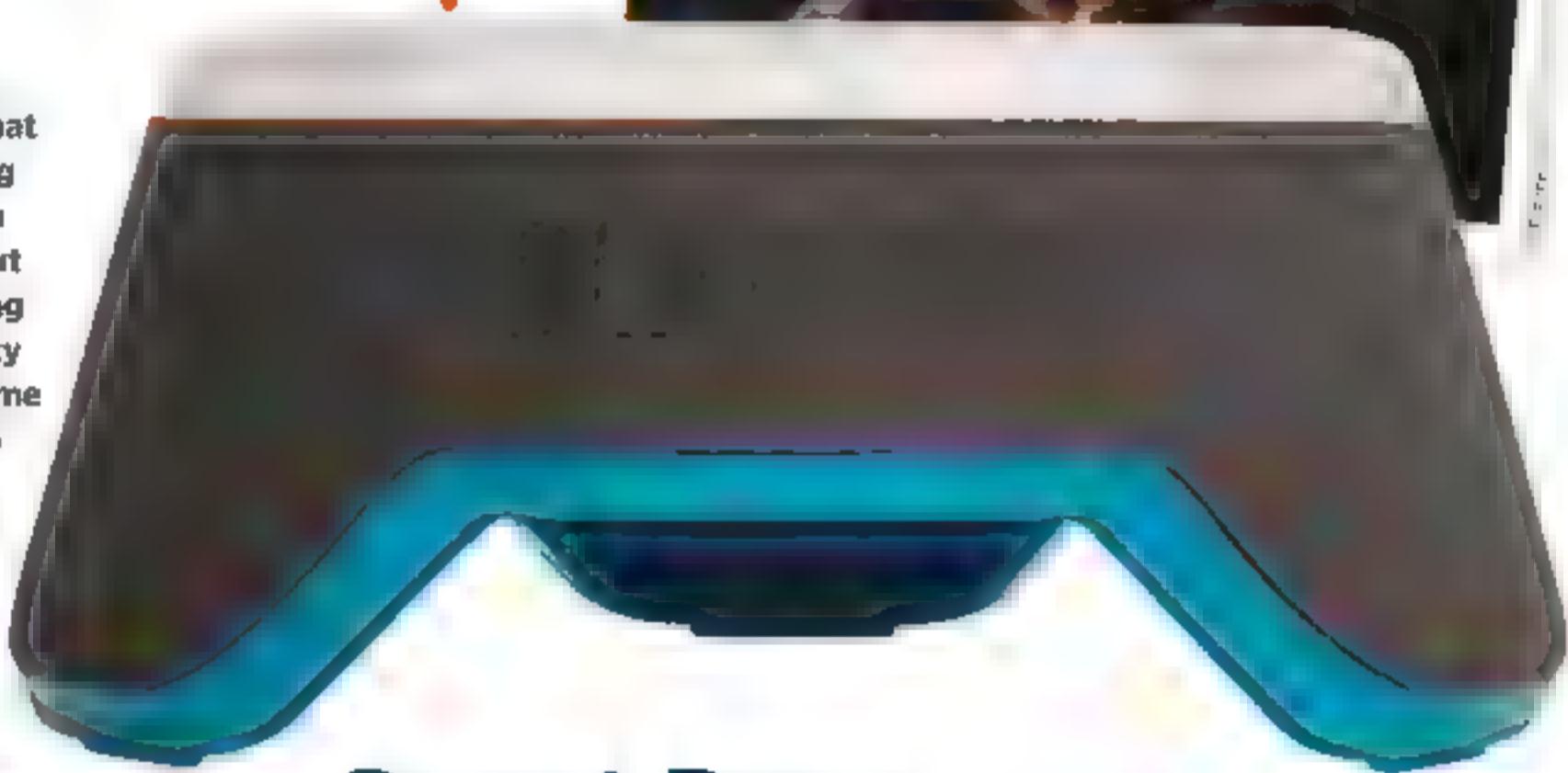
in this week's SPORT issue

## BlazePods

■ Price: \$399 (approx £330)

[blazepods.com](http://blazepods.com)

Like the whack-a-mole of workout gadgets, BlazePods are touch-sensitive light-up pods that act as a visual cue in a training session. Using either predetermined training programs or a self-designed session, these compact workout accessories are personalisable to your training needs. Intended to improve your speed, agility and reaction time, the BlazePods record the time each pod in a kit is touched, enabling you to monitor your training progress.

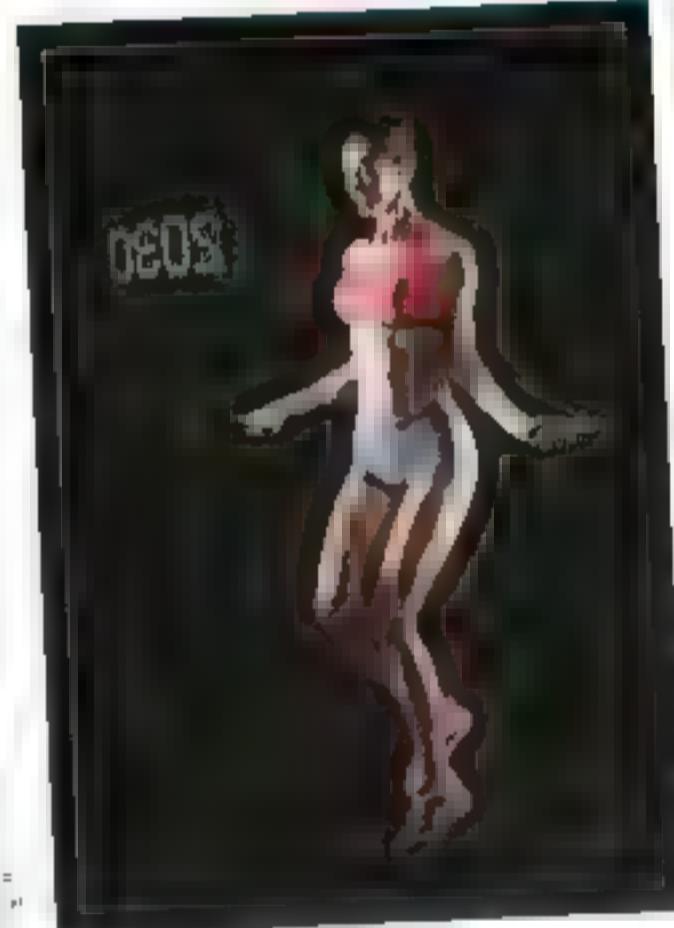


## Smart Rope

■ Price: £79.95 / \$79.95

[rangefactory.com](http://rangefactory.com)

It's difficult to imagine how a skipping rope can become hi-tech. However, the Smart Rope appears on the digital scene by recording each skip and displaying a real-time counter through LED lights. It utilises a phenomena known as the persistence of vision: 23 LED lights positioned along the rope light up at different points while skipping, which creates a glowing image of your skip number, apparently floating in mid-air. Using the accompanying Smart Gym app, the user can keep track of their skips, calories burnt and any preprogrammed training sessions.

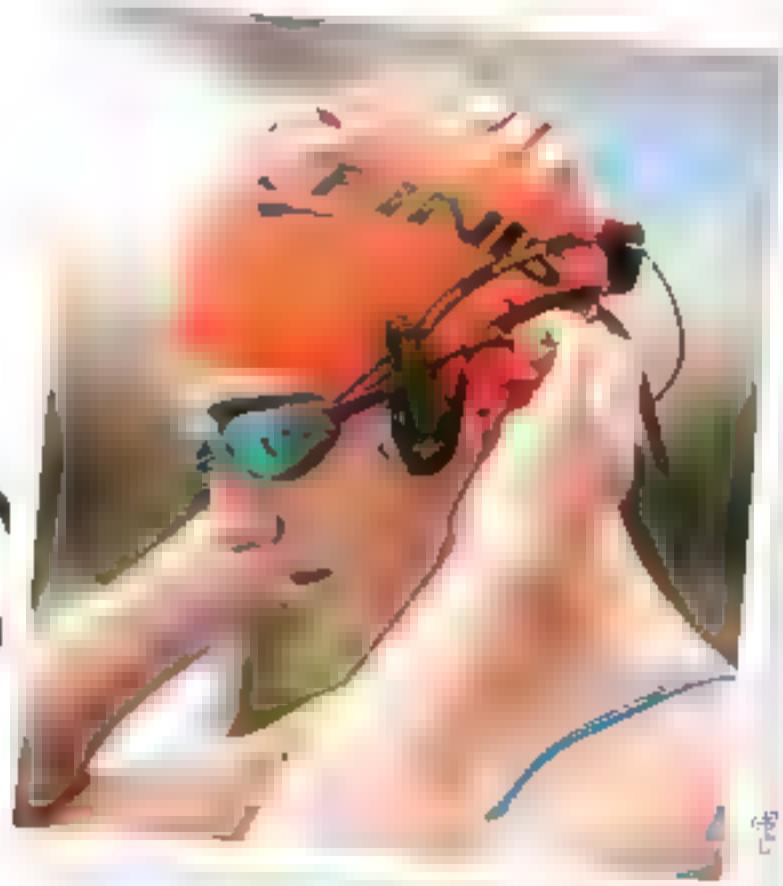


## Swim Coach Communicator

■ Price: £199 / \$149.99

[finiswin.com](http://finiswin.com)

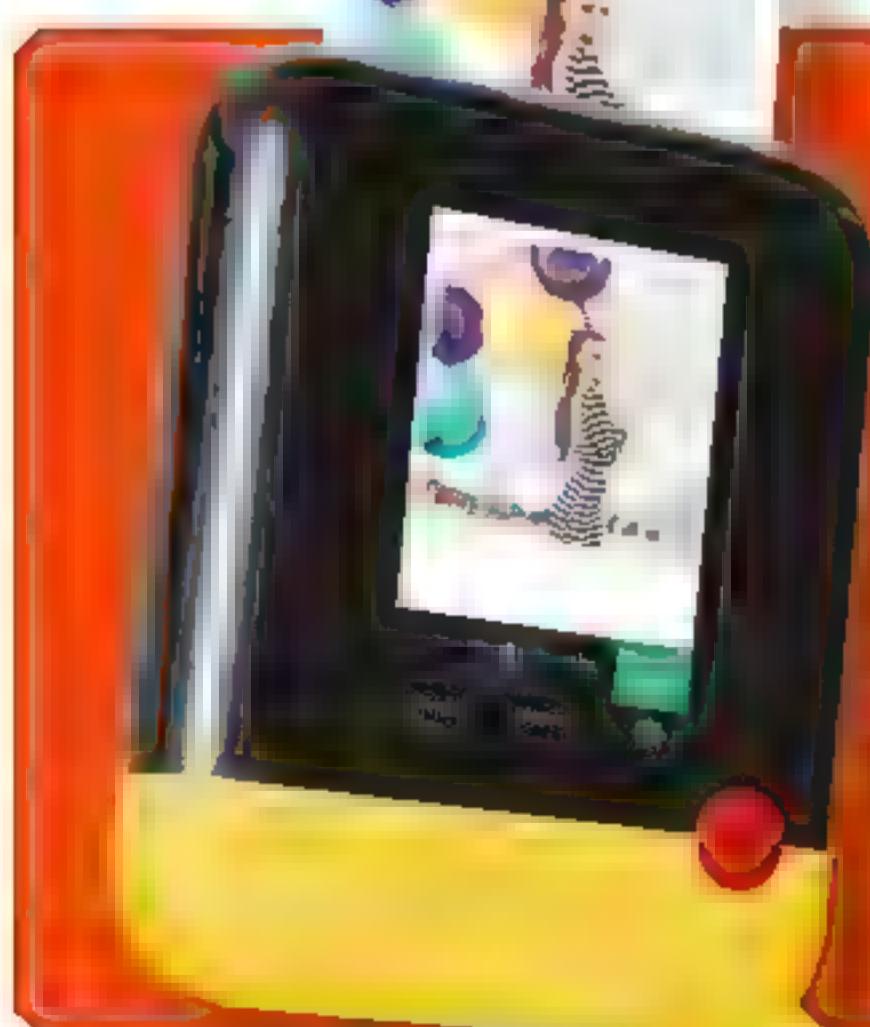
When your ears are filled with water, it's hard to hear the calls of a swimming coach while swimming. With the Swim Coach Communicator, coach and athletes can stay in contact during a swim to offer real-time instruction to improve stroke, pace and form. These simple Bluetooth-connected headphones are waterproof up to three metres, and using the FINIS live app, coaches can talk with swimmers in the pool at the touch of a button.



# Hedkayse ONE

■ Price: £150 (approx \$180)  
[hedkayse.com](http://hedkayse.com)

Ditching traditional hard polystyrene for their own unique 'Enkayse' material, Hedkayse is a first in foldable helmet design for cyclists. As a multi-impact helmet, the Hedkayse ONE can handle the bumps and scrapes of everyday life, while neatly folding into a backpack. Certified to EU safety standards, this versatile helmet is a great way to stay safe on the streets.



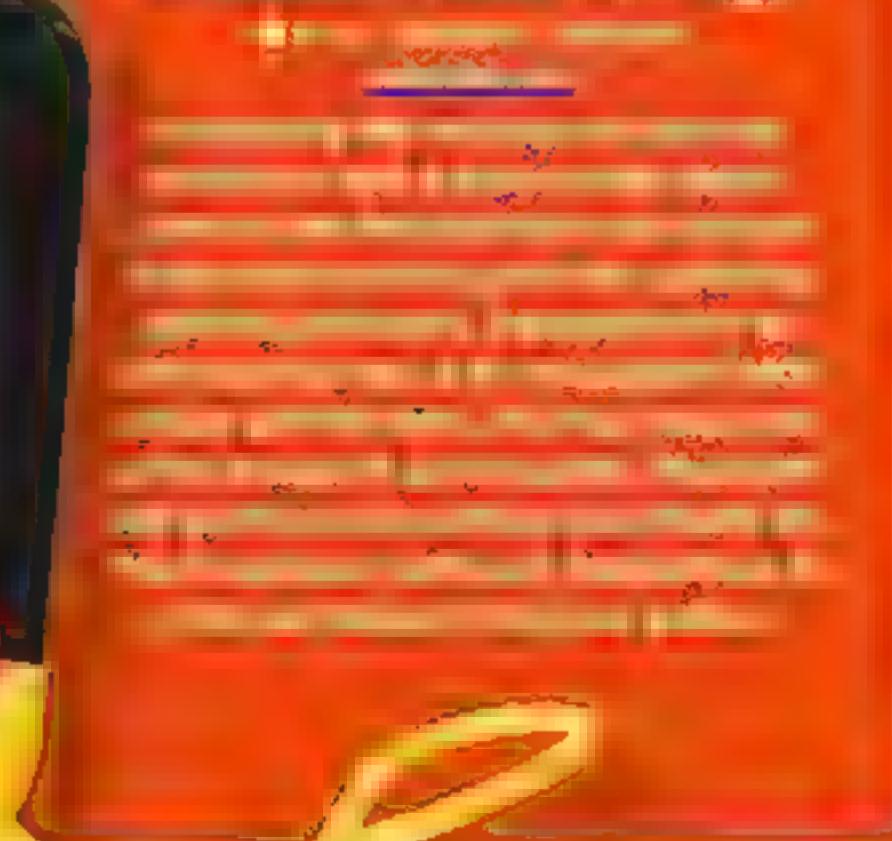
## SPT 2

■ Price: £171 / \$229.99  
[sportperformancecentral.co.uk](http://sportperformancecentral.co.uk)

Understanding how a team is performing on the field is key to achieving future success in any sports team. The SPT 2 can provide in-depth statistics of each player wearing the compact tracking device, as well as the entire team's performance. From players' highest speeds to a heat map of player positions during a game, the accompanying analytic software provides a whole host of information for tailored training.



## Polaroid Pop



## APPS & GAMES

### NBA AR Basketball

■ Developer: NBA Properties, Inc.  
■ Price: Free / Google Play / App Store

Bringing augmented reality and professional basketball together, this app enables you to virtually step onto the court to access behind-the-scenes videos as well as interactive games.



### Nike Training Club

■ Developer: Nike, Inc.  
■ Price: Free / Google Play / App Store

This personal trainer app offers users a whole range of personalised workouts and drills by Nike experts, as well as from elite athletes such as Cristiano Ronaldo.



### TacticalPad

■ Developer: Temma Software - TacticalPad  
■ Price: Free / Google Play / App Store

Plan out your team's strategy with this tactical app. Using its 3D modelling and animated features, Tactical Pad allows you to create virtual matches - great for coaching and performance analytics.

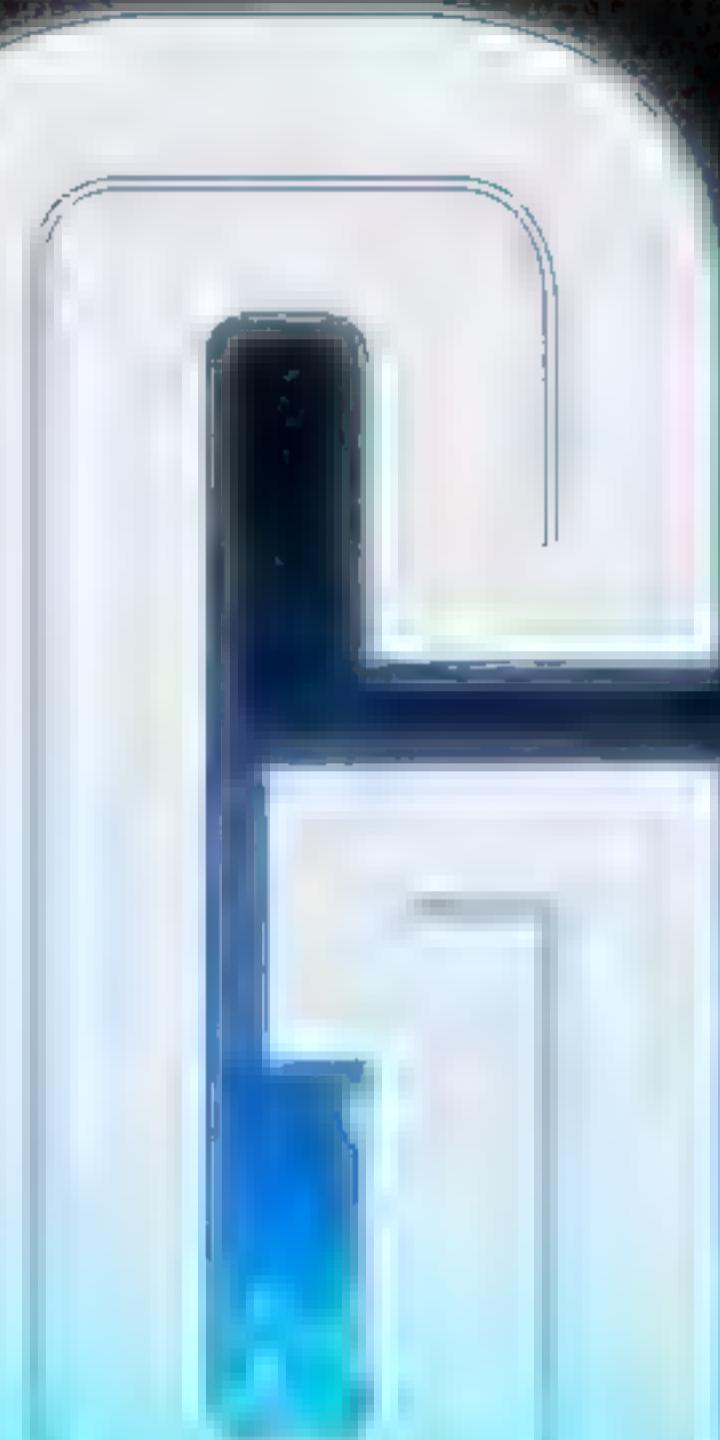


### Sleep Time

■ Developer: Azumio Inc.  
■ Price: Free / Google Play / App Store

By placing your smartphone under your pillow, track your REM and sleep cycle with this app, so you can understand how best to get a good night's sleep after a day of athletic training.





# HOW 5G WILL SUPERCHARGE YOUR LIFE

THIS ULTRAFAST MOBILE INTERNET TAPS INTO UNTOUCHED FREQUENCIES, ENABLING TECHNOLOGY THAT WILL TRANSFORM HOW WE LIVE AND WORK

Words by Jack Parsons

Look at the top-left or top-right corner of your phone screen. What does it say? The chances are it reads '4G'. If you visit a city, this might change to '4G LTE'. This means you'll get slightly faster internet. Or if you travel to the countryside, it could say '3G'. Here your video streaming might stutter. But this year, if you're in the right place with the right device, that top corner will say something new: 5G. And nothing will be the same again.

The 'G' stands for 'generation'. 5G is the fifth generation of mobile connectivity, combining pioneering research and the latest technology. But this new generation of network will change more than just how we use our mobile phones. "It will have the same impact as electricity, silicon and steam had in the previous industry revolutions," says Asa Tamsons, the head of new

businesses at Swedish telecom equipment maker Ericsson

What makes 5G different from previous generations is that it works over higher radio frequencies. While all radio waves travel at the same speed, the wavelength of a particular frequency directly affects how fast it can transmit data. As a rule of thumb, the higher the frequency, the shorter its wavelength and the more bandwidth it has to send information.

The highest frequency 4G uses is 2.6 gigahertz (GHz). The 5G phone towers that are being turned on right now transmit between 3.5GHz and 6GHz. This is why 5G can offer download speeds of up to ten gigabits per second (Gb/s) – ten times what 4G could ever achieve. This will enable you to wirelessly download HD movies in seconds, not minutes.



5G's speed will enable AR and VR to be widely used in hospitals

Of course, high-speed mobile internet isn't just about downloads. There's also latency. This is the communication delay on the network, the time lag between you sending a command – tapping a button on a webpage, for example – and the site responding. The less time it takes, the lower the latency. While 4G had a maximum latency of 50 milliseconds, 5G reduces that to just four milliseconds, giving you a near-instantaneous connection every time.

But in the next few years, 5G could get even faster, as internet providers plan to tap into the frequencies way beyond 6GHz. The part of the spectrum between 30GHz and 300GHz is known as the millimetre band for its extremely short wavelengths – just 1-10mm wide. These so-called 'millimetre waves' (or 'mmWaves') have been used for radio astronomy and radar guns in the

past. Once we start using mmWaves' blazing fast bandwidth, 5G will stop feeling like good WiFi and will deliver the benefits it promises.

However, higher frequencies come at a cost. The short wavelengths can't travel long distances and are easily disrupted. Millimetre waves, in particular, require a line of sight with the device they're sending data to and can be blocked by walls or even rain. We'll have to build more antennas in our towns and cities so that we're always close enough to pick up a signal. However, higher frequencies only need small antennas, so rather than high phone towers looming over cityscapes, transmitters will be built into lampposts and traffic lights.

These days, mobile networks aren't just about phone calls. We now have all sorts of bandwidth-demanding devices: tablets that

#### Mini data centres

Rather than transfer data back and forth to server farms kilometers away, internet providers will build mini data centres into 5G towers to further speed up local data processing



## Innovative infrastructure

The next-gen network is so new, telecoms companies are still experimenting with different ways of delivering it



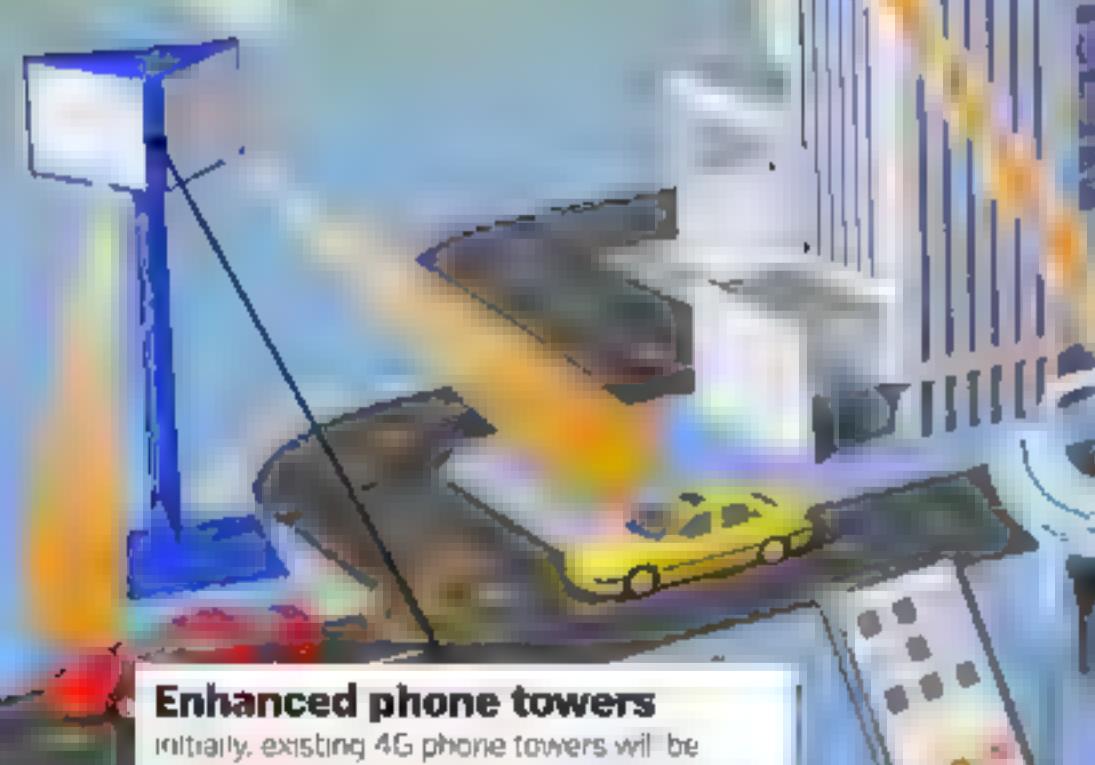
#### Indoor antennas

As mmWaves can't pass through concrete, transmitters may even have to be built inside buildings.



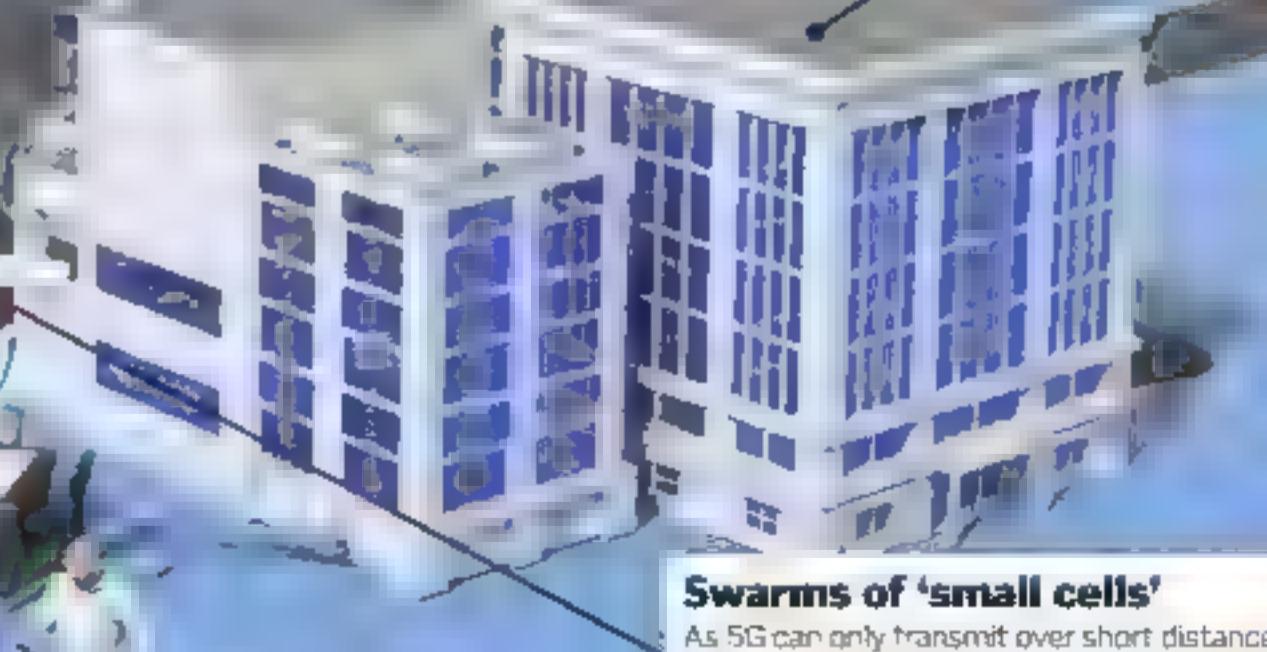
#### Enhanced phone towers

Initially, existing 4G phone towers will be upgraded to use higher frequencies (excluding mmWaves) and offer increased bandwidth.



#### Swarms of 'small cells'

As 5G can only transmit over short distances, cities will be filled with lots of miniature masts, built into lampposts and traffic lights.

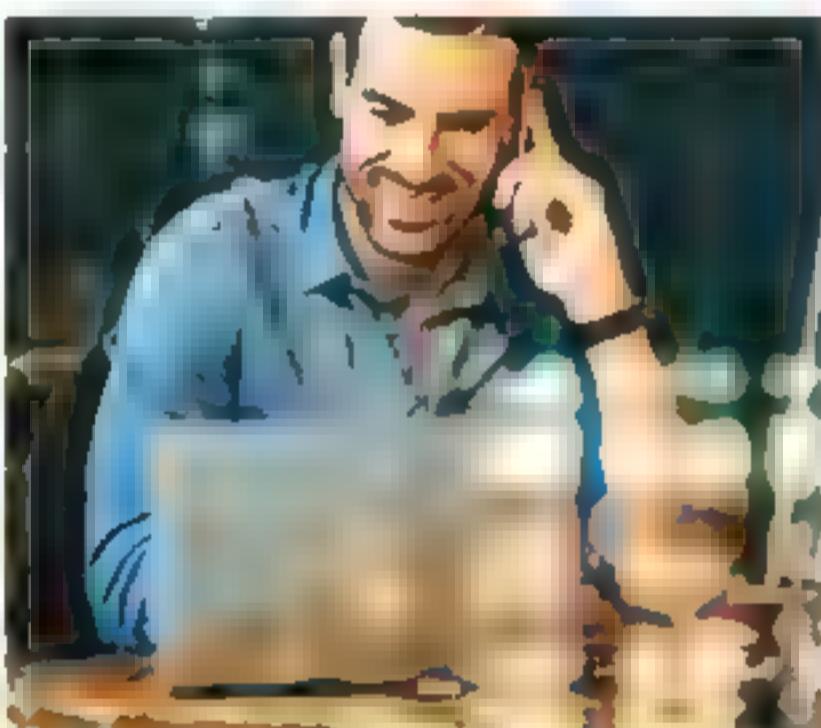




*"Rather than high phone towers looming over cityscapes, transmitters will be built into lampposts and traffic lights"*



Not just an urban boon, 5G will benefit rural businesses and communities too



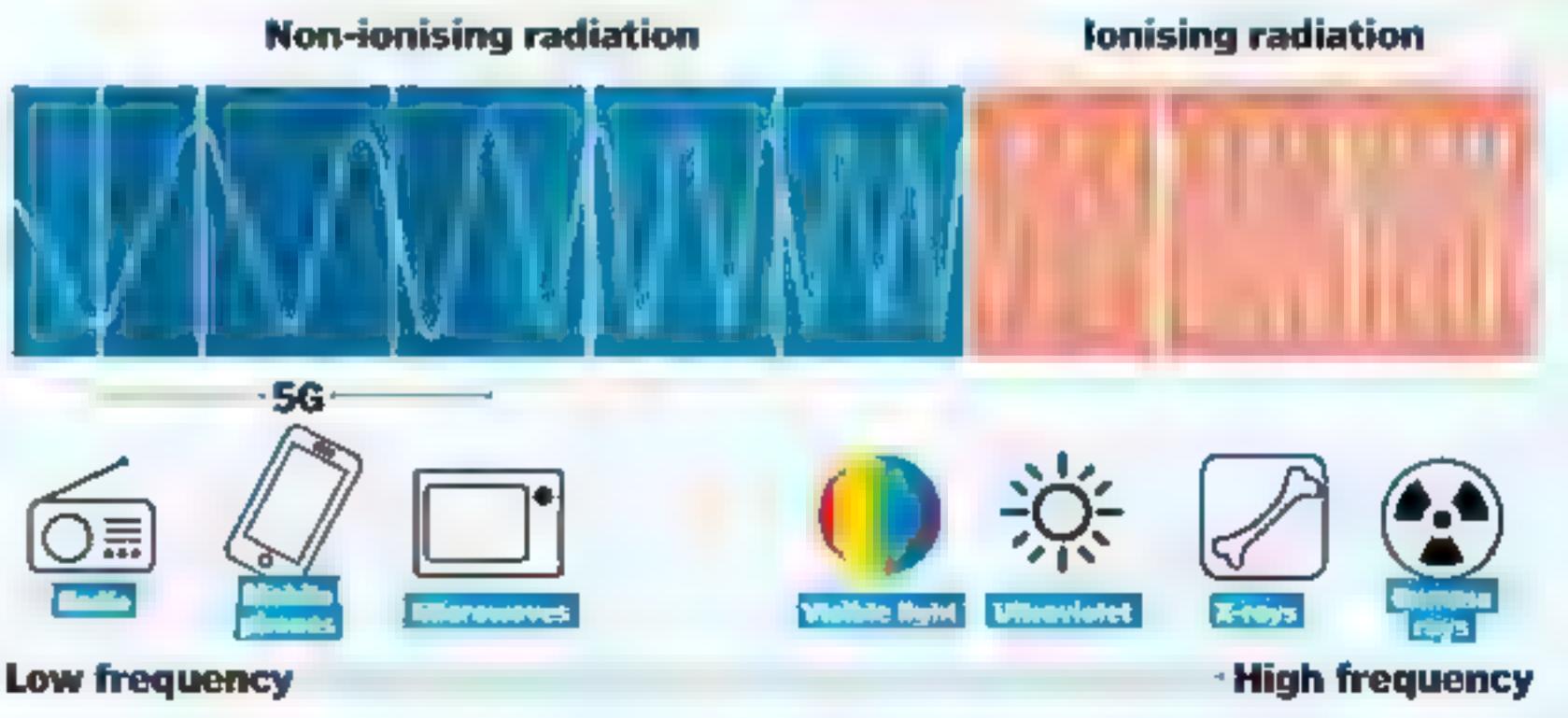
5G will enable people to work and stay connected on the go more easily

## Zapping users with data beams

5G is a mobile technology that promises to revolutionise the way we live and work. It offers speeds up to 100 times faster than 4G, making it ideal for streaming video, playing online games, and using virtual reality. 5G also has the potential to transform industries such as manufacturing, healthcare, and transportation. One of the key features of 5G is its ability to connect a large number of devices simultaneously, making it ideal for the Internet of Things (IoT). Another benefit of 5G is its low latency, which is essential for real-time applications such as autonomous vehicles and remote surgery. Overall, 5G has the potential to bring about significant improvements in connectivity and efficiency across a wide range of sectors.

## Where does 5G sit on the EM spectrum?

The electromagnetic (EM) spectrum describes all wavelengths, including the visible light we can see and many we can't, like microwaves and x-rays. Radio waves sit at the non-ionising end, with the lowest frequencies and longest wavelengths. Dangerous gamma rays sit at the ionising end, with the highest frequencies and shortest wavelengths, which can damage DNA and cause cancer. While 5G uses higher frequencies than 4G – including millimetre waves – these remain within the 3kHz to 300 GHz radio wave band.



# Everyday 5G

While it'll take time for the network to reach its top speeds, 5G will have instant benefits (if you live in the right place)

## Better business

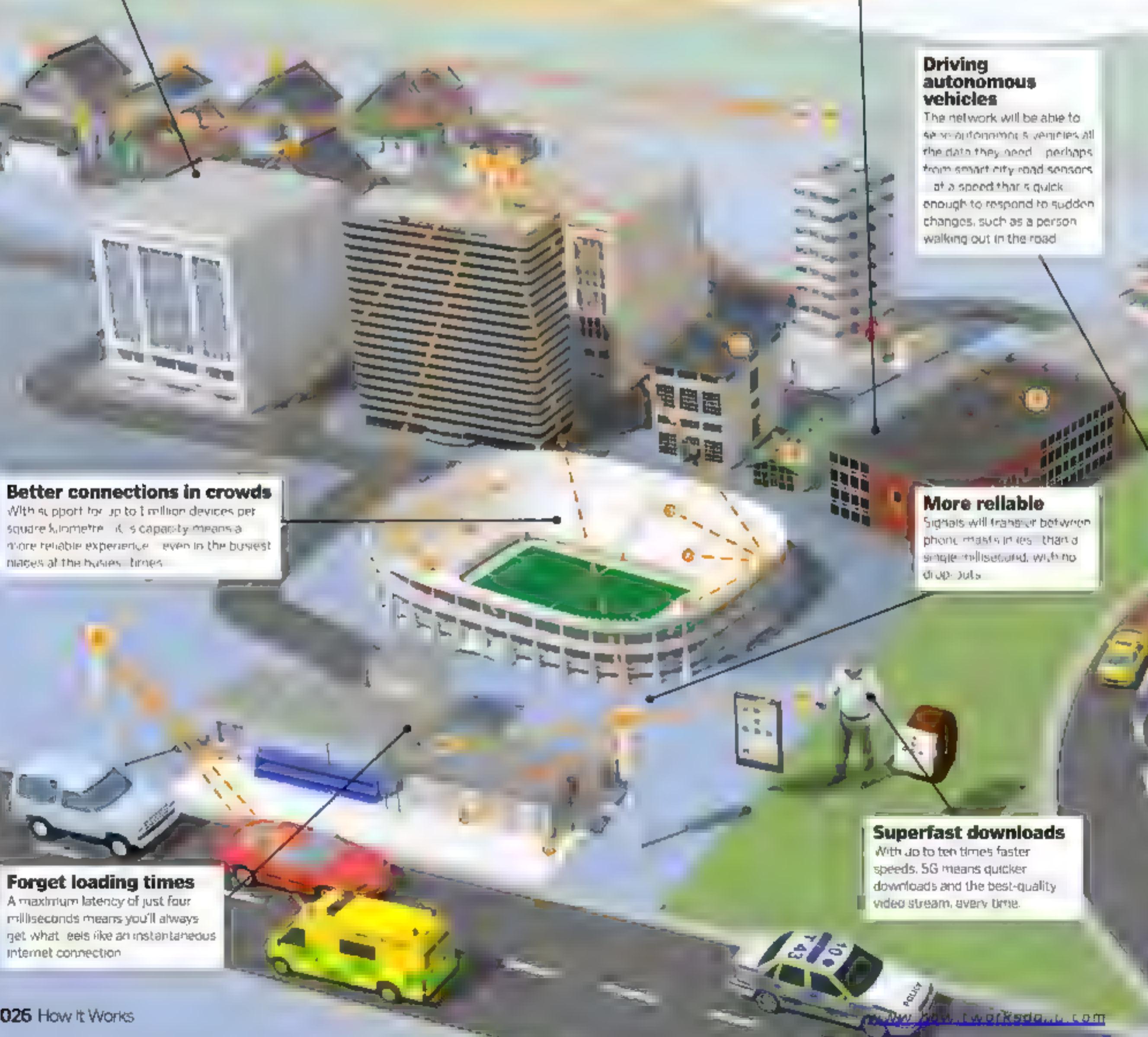
By having a much faster and more reliable network, businesses – big and small – are expected to benefit hugely from 5G. A 2017 report by PwC Research stated that 69 per cent of businesses expected their productivity to increase

## More energy efficient

Smart software will give telecoms companies better control over networks, so they can make sure there's always enough bandwidth and the system uses less power

## Smarter classrooms

Augmented reality and virtual reality lessons will be available to students in a 5G-enabled schools, and teachers could deliver lessons remotely in real time, if free



## Better connections in crowds

With support for up to 1 million devices per square kilometre, 5G's capacity means a more reliable experience – even in the busiest places at the busiest times

## Forget loading times

A maximum latency of just four milliseconds means you'll always get what feels like an instantaneous internet connection

## Driving autonomous vehicles

The network will be able to send autonomous vehicles all the data they need – perhaps from smart city road sensors – at a speed that's quick enough to respond to sudden changes, such as a person walking out in the road

## More reliable

Signals will transfer between phone mast and user in under a single millisecond, with no drop-outs

connect to the cloud so people can work on the go, smartwatches that have their own data plans and household gadgets like always-on HD security cameras. This trend is expected to continue, with the world going from 8.4 billion internet-connected devices two years ago to over 20 billion by 2020 – tripling the amount of mobile data we use.

Fortunately, 5G is up to the job. The shorter wavelengths it uses also give it more capacity, meaning the network can handle more information at one time. So while 4G could connect 100,000 devices per square kilometre, the next-gen network will handle 1 million.

Not only is this high capacity future-proof, but it will set the so-called 'internet of things' (IoT)

into hyperdrive. Thousands of everyday objects – from your home to your work to the street corner – will be fitted with sensors, collecting, transmitting and sharing data. All of this information can be combined and analysed in the cloud, helping homes, businesses and whole communities make smarter decisions.

This technological leap forward will lead to new products, businesses and even industries, from self-driving cars to artificial intelligence. Experts say 5G could drive an extra \$1.2 trillion of annual sales by 2035. That's about the size of China's entire economy. It's perhaps no surprise then that countries, as well as companies, are racing to embrace 5G.

The first step is to get the infrastructure in place. Nokia, Ericsson and Huawei are the top three equipment providers for networks. However, the US has banned Huawei from being

Advertise!

#### Advertise anywhere

Marketeers will be able to place video and interact with practically any surface, anywhere. Ultra-slim transmitters (receivers) have become small and cheap enough; even grocery packaging could have interactive displays.

#### More productive farms

5G drones and remote sensors can track the details of individual animals, plant health, soil quality and water salinity (in fish farms), enabling farmers to be more efficient.

## Q&A

### Is 5G hazardous to your health?

Dr David Robert Grimes, cancer researcher and physicist, discusses fears over 5G

The UN's International Agency for Research on Cancer (IARC) has classified radio-frequency radiation (RFR) – which includes mobile signals – as "possibly carcinogenic". Should we be worried?

This isn't especially worrying, oddly enough. IARC classification is based on the strength of evidence for a particular agent having a cancer risk, not the degree of severity of that risk. RFR is classed as 2B, which effectively means there's no reliable evidence that there's any cancer risk associated with it. IARC's system is ripe for confusion, so it's understandable this classification can worry the unwary.

Is there any evidence suggesting mobile phones are linked to tumours?

There really isn't. Firstly, from a biophysics perspective, the radio frequency of radiation used in mobile phones is strictly non-ionising, so we wouldn't expect it to be able to cause the kind of DNA damage that leads to cancer. Secondly, despite rates of phone use going from almost nothing to high-on 100 per cent in just over two decades, we're not seeing any evidence of increased brain tumours, which is what you'd expect to see if there was an effect, as we hold phones to our ears for long stints. To take one example of many, the 29-country Interphone study observed no increase in the risk of common brain cancers correlated with phone use. There is simply no epidemiological data that phones are linked to tumours.

5G requires hundreds of transmitter masts, positioned closer to ground level. Does this mean they'll be giving off more radiation? Not at all. 5G needs more transmitters because it's more easily attenuated by the environment and can't travel as far. To overcome this, you need more transmitters – but it doesn't mean they'll be giving off more radiation.

Why do you think 5G health risks have prompted conspiracy theories?

Anxiety over 5G isn't unique – we've seen similar unfounded panics in the past on everything from vaccination to water fluoridation to mobiles. What's difficult to address is the fact misinformation can perpetuate further and faster than ever before, allowing scaremongering stories to spread.

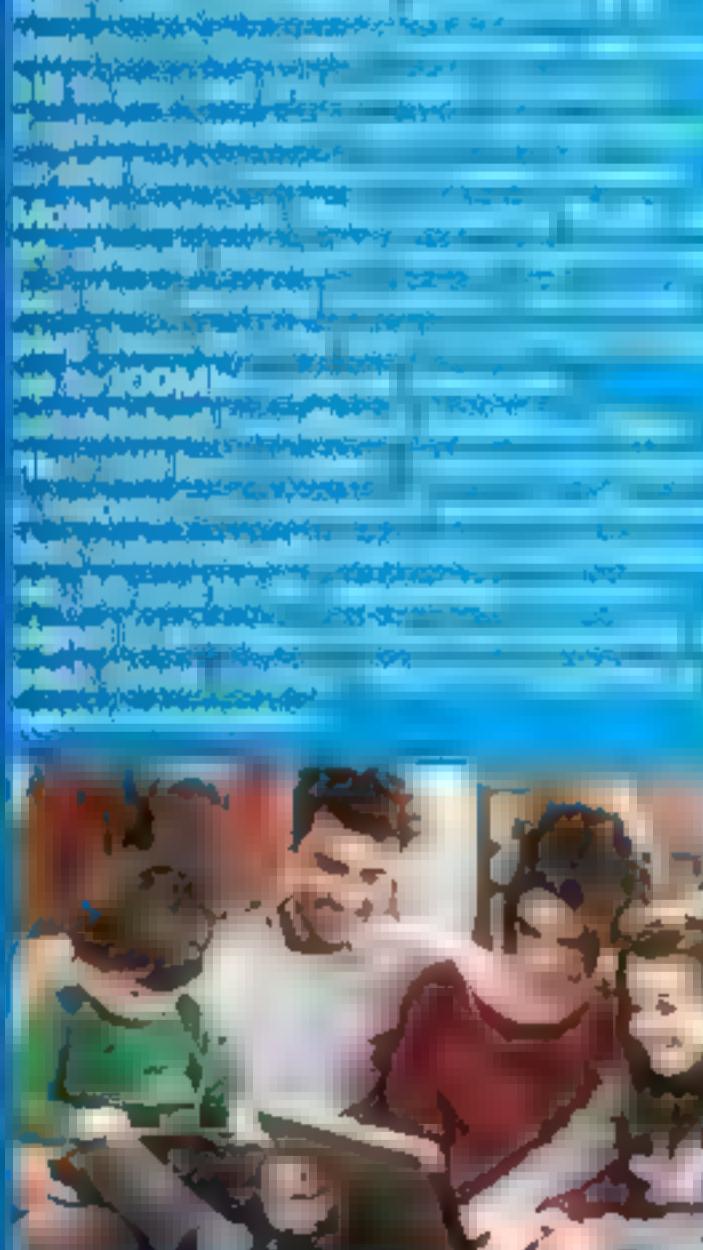
Involved in certain networks, amid allegations its equipment could be used to help Chinese spying. It's a charge the company strenuously denies. Australia has followed the US's lead. Germany is now tightening up its law on telecoms security standards, but the UK has said it's still willing to work with Huawei.

South Korea was the first to roll out 5G nationwide, with all of its leading telecoms companies switching on their new networks in April. Despite being significantly larger, both China and the US aim to achieve the same thing in 2020. Up to 25 cities in the UK will offer 5G by the end of the year, with the first six in May. Switzerland, though, is leading the pack in Europe, rolling out 5G in 227 areas.

Next will come the phones. 5G will need a next-gen modem, so older phones won't support the new speeds. Many top phone makers have committed to making (or have already launched) 5G-ready smartphones. These include Samsung, Huawei, OnePlus, LG, Xiaomi and Oppo.

Initially, 5G will be targeted at businesses, but this will ultimately benefit all of us. Faster speeds and lower latency for businesses will mean faster responses and better services for consumers. The 5G future is coming along faster than you expect.

## Goodbye broadband?



## The future of 5G

How 5G will be utilised by businesses and communities



### Eliminating traffic jams

While we've been talking about self-driving cars for years, they might finally hit the road with 5G in the future. Autonomous vehicles could be the norm, with better managed entry by 5G systems that can make traffic jams a thing of the past.

### Feeding AI brains

Artificial intelligence (AI) works using algorithms. By inputting a mix of data sets and expected outcomes, it can learn to spot patterns. The more data you feed in, the smarter it gets. And 5G will create a massive amount of data. AI may even ultimately manage 5G's incredibly complex networks.



### Making drone deliveries

Just as 5G will allow self-driving cars to steer themselves, this technology can do the same for drones, providing them with information so they can zoom above our heads. This will lead to super highways in the sky filled with parcel delivery drones and possibly unmanned flying taxis.

## The evolution of mobile networks



**1940**  
Also called 0G, the first mobile radio telephones are more like walkie talkies, only allowing two-way communication and fit in a whole suitcase.

**1979**  
Launching in Japan, 1G allows users to make calls on the go. The phones are chunky, with limited battery, and the signal is poor.  
Max speed: 2.4Kb/s

**1990**  
2G's big improvement is to switch from analogue to digital, improving the call quality and making it possible to send data.  
Max speed: 64Kb/s

**1992**  
The world's first text message is sent in the UK, reading 'Merry Christmas' from software developer Neil Papworth to his Vodafone boss, Richard Jarvis.



**1 Antennas all over**

As millimetre waves are easily disrupted, phones will have to be built in a way so that hands don't cover up the receiver at any time. One solution is to stash tiny antenna arrays in every corner.

**2 Longer-lasting batteries**

For now, switching between 5G and 4G might drain your battery. But as coverage expands and phones are fitted with more efficient 5G modems, you can actually expect to get something of an energy boost.

**3 Bigger price tags**

These superfast smartphones will be expensive initially, as will phone plans. But the price will drop over time – just like it did with the launch of 4G.

**4 Android only – for now**

Samsung, Xiaomi and OnePlus are all selling 5G versions of their flagship handsets. Meanwhile, experts don't expect Apple to launch a 5G iPhone until next year.

**5 8K cameras**

Chinese smartphone maker Nubia already sells a phone that shoots 48-megapixel pictures and 8K video, so with more bandwidth to play with, it's hard to imagine this trend not catching on.



**1998**  
Finland's Radiolinja launches the first downloadable content sold for mobile phones, the ringtone. These beeping jingles become hugely popular worldwide.



**2001**  
Mobile phones go online with 3G. It isn't that fast but you can surf the web, send emails, stream music and even make video calls.  
**Max speed: 2Mb/s**



**2007**  
The first iPhone launches. Though it's criticised for not offering 3G, the touchscreen device shows how smart the new smartphones can be.



**2009**  
Debuting in Norway and Sweden, 4G is ten times faster. It makes HD video streaming, gaming and cloud computing possible.  
**Max speed: 100Mb/s**



**2018**  
In December 3GPP, the organisation that manages mobile standards, agrees what spectrum 5G will use giving the telecoms industry the green light.



**2019**  
South Korea is the first country to roll out 5G nationwide in April, with the rest of the world not very far behind.  
**Max speed: 1+Gb/s**

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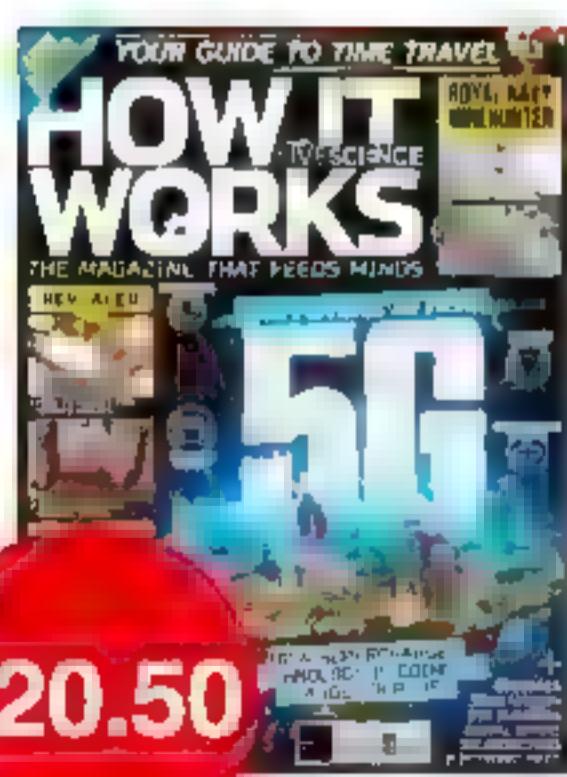
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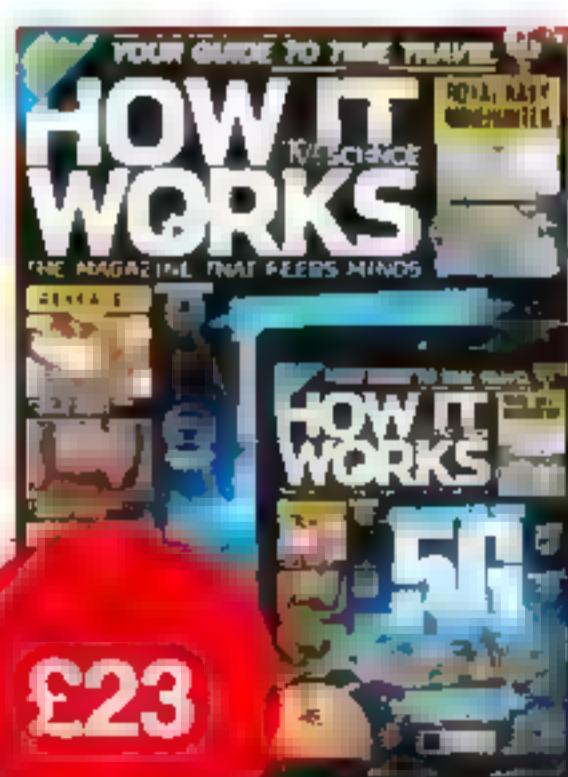
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# The science of lie detectors

Do polygraphs really reveal the truth, the whole truth and nothing but the truth?

**S**ince the early 1920s 'lie detectors' have been used to evaluate whether or not someone is being deceitful by measuring their physical responses to a series of questions. Elevated blood pressure, a higher breathing rate and increased sweating are all indications that a person may be telling a lie.

A polygraph (lie detector) test, is a method that capitalises on these biological signals of lying to sniff out the truth. Hooked-up to a series of sensors, these signs are recorded during the test. The subject is initially asked baseline questions to establish a normal rate of blood pressure, breathing rate and perspiration. The interviewee is then repeatedly asked questions targeted to evaluate whether the answer is deception or truth. The examiner conducting the interview monitors the information coming in from each sensor to see when a spike on the chart occurs – the sign that a deceptive answer may have been given.

This form of lie detection, however, isn't an exact science and has sparked controversy about its legitimacy. A polygraph's ability to collect vital data hasn't been called into question, but how that information is interpreted is debated. Sitting strapped to several wires while an interviewer asks you probing questions is enough to make anyone sweat. Therein lies the main problem with polygraphs. The experience of taking a test can cause enough stress and spikes in blood pressure and respiratory rate to suggest a lie. Similarly, there are ways that people can suppress these changes during an interview.

This doubt in its validity has led to most US and UK courts to ban polygraph data as evidence of guilt or innocence during a trial.

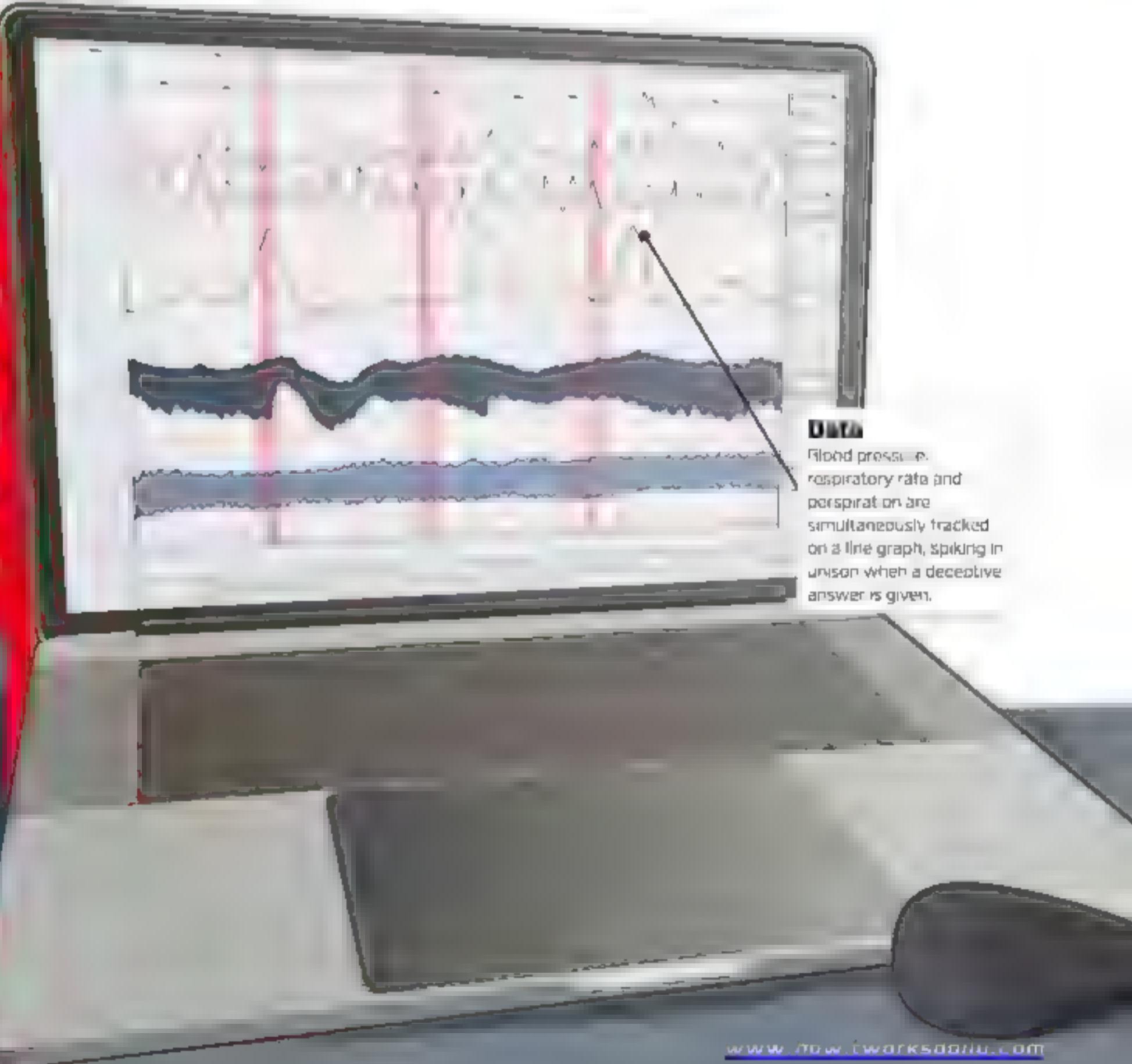


'Poly' in ancient Greek means 'many' so a polygraph is named due to the many graphs created at once

**"This doubt in its validity has led to most US and UK courts to ban polygraph data"**

## Reading the mind

As 'mind-reading' technology continues to advance, could the brain itself be used to take a polygraph test? Brain-Computer Interface (BCI) technology is making scientific waves for its ability to open a window into the mind and further our understanding of the body's control centre. By analysing the electrical activity of the brain's neurons, using a wearable device called an electroencephalogram (EEG), researchers may be able to know if someone is lying by listening to their brain. Earlier this year a study published in the *Journal of Physics* found that when confronted with images of jewellery items that 'guilty' study participants had stolen, the EEG detected spikes in the brain's electrical activity compared to 'non-guilty' participants who were shown the same images.



## Deciphering deception

How a polygraph sniffs out a liar

### Interrogation

Interviewees are asked a series of predetermined questions to evaluate deception alongside control questions for comparison.

### Breathing rate

Known as a pneumograph, two air-filled tubes are strapped across an interviewee's chest to measure their respiratory rate. During breathing the chest expands and contracts to displace the air in the tube which is then recorded.

### Sweating

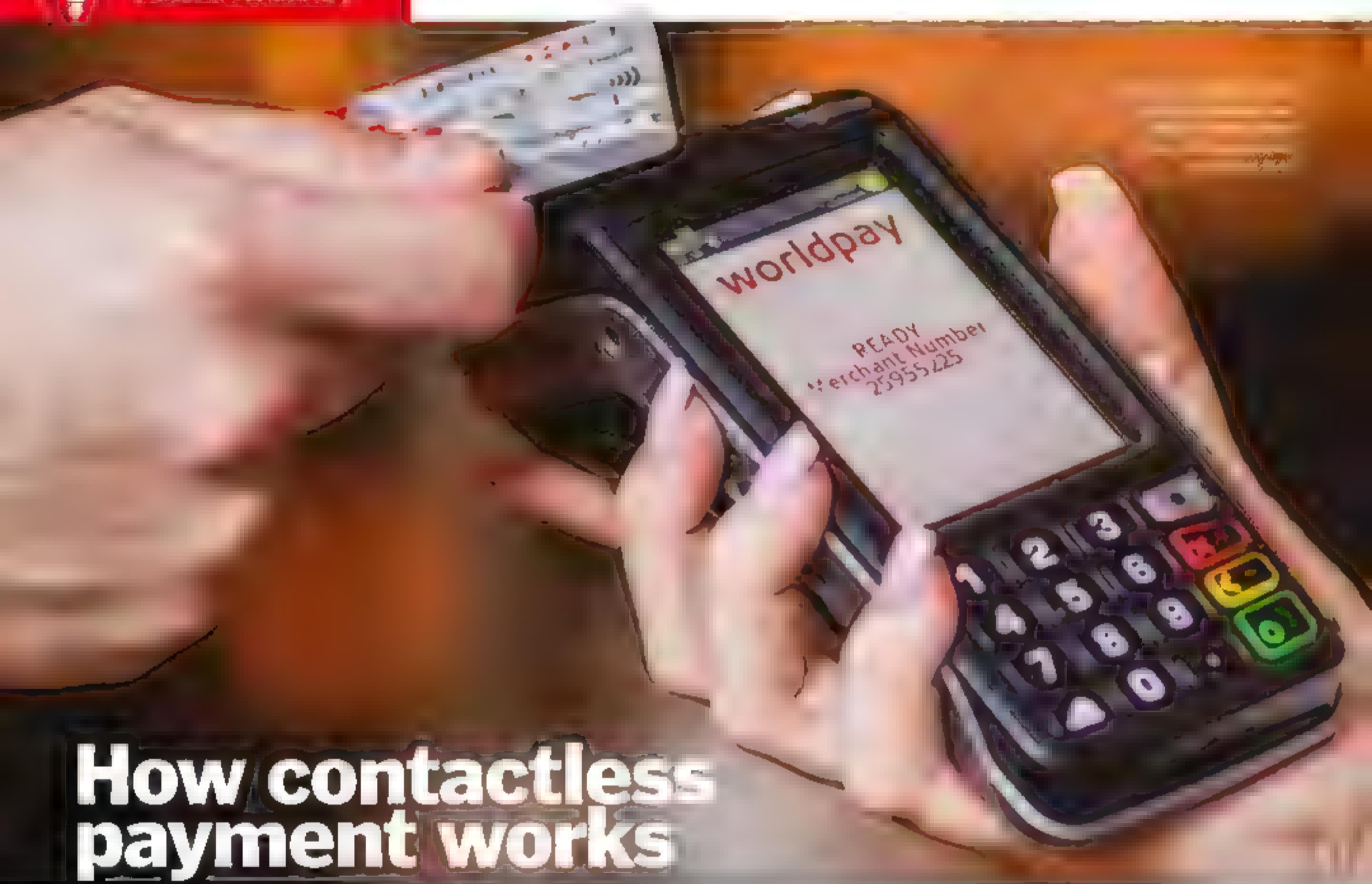
Galvanic skin response (GSR) is measured to monitor a person's sweat levels. Sensors are placed on the fingers to record how electrically conductive they are. More sweat equals more conductivity.



The first 'lie detector' was invented by John Augustus Larson back in 1921

### Blood pressure

Using a blood pressure cuff, the sound vibrations of blood passing through vessels displace the air in the connecting tubes. Changes in the displacement are converted into electrical signals by the use of transducers.



# How contactless payment works

The original aircraft-tracking technology has evolved to change the way we pay

In the UK, when you tap your contactless card you can spend up to £30 in the space of a second. Some people love it, some people are unnerved by it, but have you ever left the till wondering how it can be so straightforward?

These payments use technology called radio frequency identification (RFID). Today there is rising demand for this equipment, with contactless payment being the most common method for in-store card transactions. RFID enables encoded digital data to be transferred via radio waves between two devices. In the case of contactless payment, data is provided between a card and card reader. While they need to be in close proximity to establish a connection, they do not need to come into contact. This form of RFID, used in transmitting data over short distances, is called near-field communication (NFC). NFC technology has gone a step further in speedier payments by enabling people to pay contactlessly using a smartphone.

The recent developments have definitely drawn more awareness to RFID, but when did it first come about? This seemingly modern technology actually emerged before World War

II. Sir Robert Watson-Watt is believed to be the first to use radio to obtain data in this manner when he discovered a way to source information about aircraft. His system, radar, was able to detect and reveal limited data about planes, such as its size and whether an aircraft was friend or foe.

The next major progression for RFID was creating affordable commercial applications. Security tags for shops followed, with a

simplified early system that only required shopkeepers to switch tags between their two states so that they didn't trigger the door alarm. In 1973, a more complex version was created; an active tag with rewritable memory.

Further advancements in RFID have seen a variety of applications, from tracking transportation of nuclear materials to identifying individual cows for agricultural purposes, come into widespread use.

## Avoiding contactless crooks

It can be easy to get lost in the convenience of a contactless lifestyle, forgetting the potential dangers. While it has become easier for you to pay, this new method means that thieves can 'pickpocket' digitally. Using an app that costs just 25p and has been downloaded 2 million times, people can gather the credit card details of anyone within range. This method of stealing data using RFID is called 'skimming'. However, there are now precautions you can take to enjoy the perks of contactless while keeping your details safe. Wallets like the Ekster wallet are designed to block transmissions, as they encase your cards in a protective aluminium card holder. These work because radio waves cannot travel through all materials. The thin metal layer prevents signals travelling in either direction.



The Ekster wallet has an inbuilt aluminium card holder

## The science behind the tap

What goes on in that split second when you pay contactlessly

### An intricate design

Built into the address card is a small microchip containing account information. A connected copper wire increases the area for detecting signals.

## Two-way communication

The card's microchip returns a signal, responding with payment details so the transaction can be processed.

## Top-secret coding

The IoT application takes place using an encrypted language to avoid framing.

**"Thieves  
are now  
able to  
pickpocket,  
digitally"**

## Understanding RFID

An RFID system contains three parts: a tag that is programmed with information, an antenna that scans the tag and an application for the decoded data. The antenna releases radio frequency signals to

search for devices and provide the RFID tag with the energy it needs to transfer its data. Using energy from the antenna, and often no batteries, the tag can sometimes be used for decades. When the

Tag comes into contact with the antenna's emitting waves, its chip is activated. This allows the antenna to pick up its information and transfer the results to an RFID computer program.



## RFID around the world

**17**  
million

Contactless journeys are made on  
London transport each week.

**30%**

## More is spent by consumers: via contactless payments

03

millimetres  
squared

### The size of the smallest manufactured RFID tag:

1/10

■ Of adults now use cash once a month or less

# 4cm

The maximum range for a contactless card payment.

# A BEGINNER'S GUIDE TO TIME TRAVEL

Learn exactly how Einstein's theory of relativity works, and discover how there's nothing in science that says time travel is impossible

Words by Andrew May

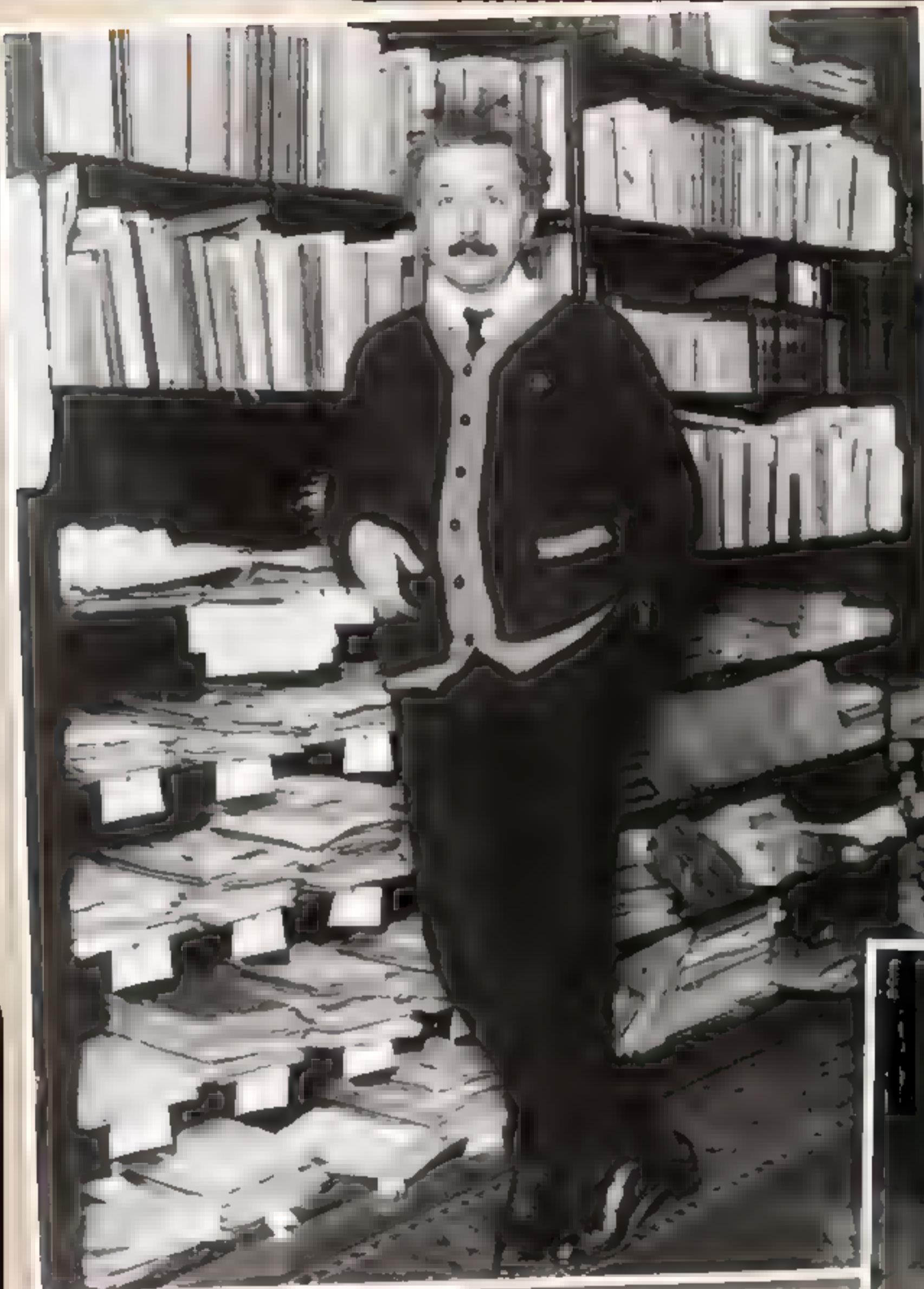
**E**veryone can travel in time. You do it whether you want to or not, at a steady rate of one second per second. You may think there's no similarity to travelling in one of the three spatial dimensions at, say, one metre per second. But according to Einstein's theory of relativity, we live in a four-dimensional continuum – spacetime – in which space and time are interchangeable.

Einstein found that the faster you move through space, the slower you move through time – you age more slowly. In other words: One of the key ideas in relativity is that nothing can travel faster than the speed of light – about 300,000 kilometres per second (or one light year per year), but you can get very close to it. If a spaceship was flying at 99.99999999 per cent of the speed of light, you'd see it travel a light year of distance in just over a year of time.

That's obvious enough, but now comes the weird part. For astronauts onboard, the journey would take a mere seven weeks. It's a consequence of relativity called time dilation, and its effect it means the astronauts have jumped about ten months into the future.

DID YOU KNOW? Because of the time its light takes to reach us, we see the Sun as it was eight minutes in the past

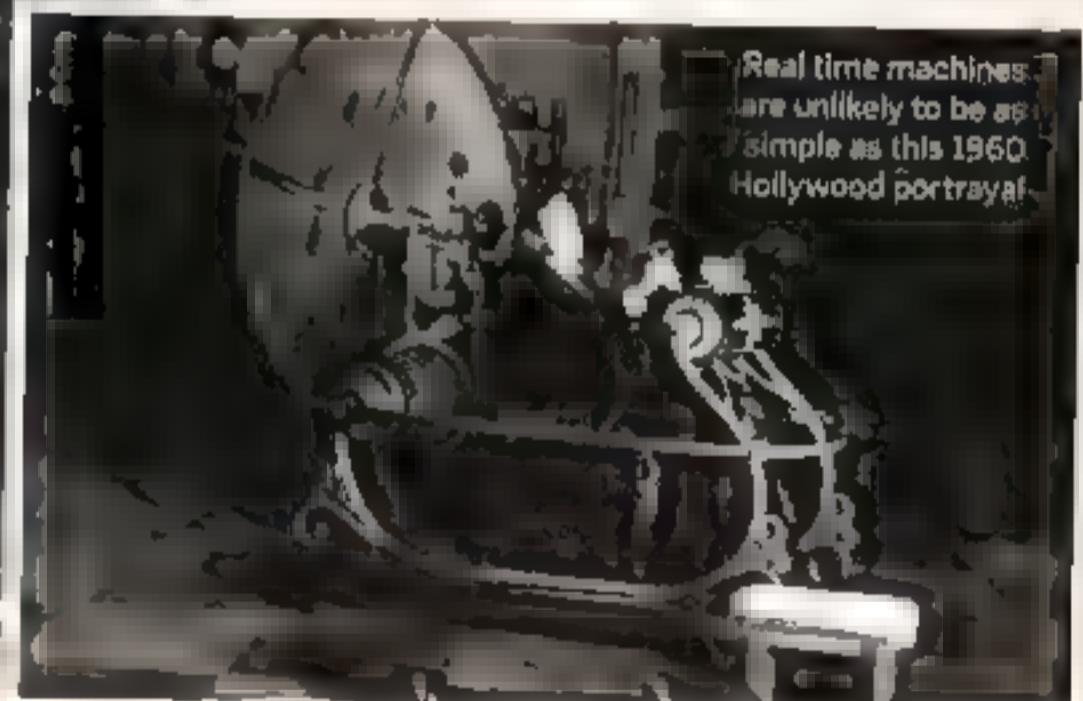




Albert Einstein, whose name has become virtually synonymous with relativity

Travelling at high speed isn't the only way to produce time dilation. Einstein showed that gravitational fields produce a similar effect – even the relatively weak field here on the surface of the Earth. We don't notice it, because we spend all our lives here, but 20,000 kilometres higher up gravity is measurably weaker – and time passes more quickly, by about 45 microseconds per day. That's more significant than you might think, because it's the altitude at which GPS satellites orbit the Earth, and their clocks need to be precisely synchronised with ground-based ones for the system to work properly. The satellites have to compensate for time dilation effects due both to their higher altitude and their faster speed. So whenever you use the GPS feature on your smartphone or your car's satnav, there's a tiny element of time travel involved. You and the satellites are travelling into the future at very slightly different rates.

But for more dramatic effects, we need to look at much stronger gravitational fields, such as those around black holes, which can distort spacetime so much that it folds back on itself. The result is a so-called wormhole, a concept that's familiar from sci-fi movies but actually originates in Einstein's theory of relativity. In effect, a wormhole is a shortcut from one point in spacetime to another. You enter one black hole and emerge from another one somewhere else. Unfortunately, it's nothing like as practical



Real time machines are unlikely to be as simple as this 1960 Hollywood portrayal

## A BRIEF HISTORY OF TIME TRAVEL

1895

H.G. Wells's novel *The Time Machine* popularises the idea of time as the fourth dimension, through which it might be possible to travel by analogy with the three spatial dimensions.

1905

Einstein's groundbreaking paper on the theory of relativity introduces the idea of time dilation – the first hint that, in real physics as well as sci-fi, time might be interchangeable with space.

1927

The physicist Arthur Eddington first introduces the concept of the 'arrow of time', and its relation to entropy, in his book titled *The Nature Of The Physical World*.

1935

Together with Nathan Rosen, Einstein shows that under certain circumstances it's possible to have a shortcut between two different points in spacetime – a wormhole even between past and future.

# WELCOME TIME TRAVELLERS



## "Everything not forbidden is compulsory"

a means of transport as Hollywood makes it look, because the black hole's gravity would tear you to pieces as you approached it, but it really is possible in theory. And because we're talking about spacetime, not just space, the wormhole's exit could be at an earlier time than its entrance, so you'd end up in the past rather than the future.

Trajectories in spacetime that loop back into the past are given the technical name 'closed timelike curves'. If you search through serious academic journals, you'll find plenty of references to them – far more than you'll find to 'time travel'. But in effect, that's exactly what closed timelike curves are all about.

There's another way to produce a closed timelike curve that doesn't involve anything quite so exotic as a black hole or wormhole: a simple a rotating cylinder made of super-dense material. Called a Tipler cylinder, it's the closest that real-world physics can get to an actual, genuine time machine. But it's not something that's ever likely to be built in practice, so like a wormhole it's more of an academic curiosity than a viable engineering design.

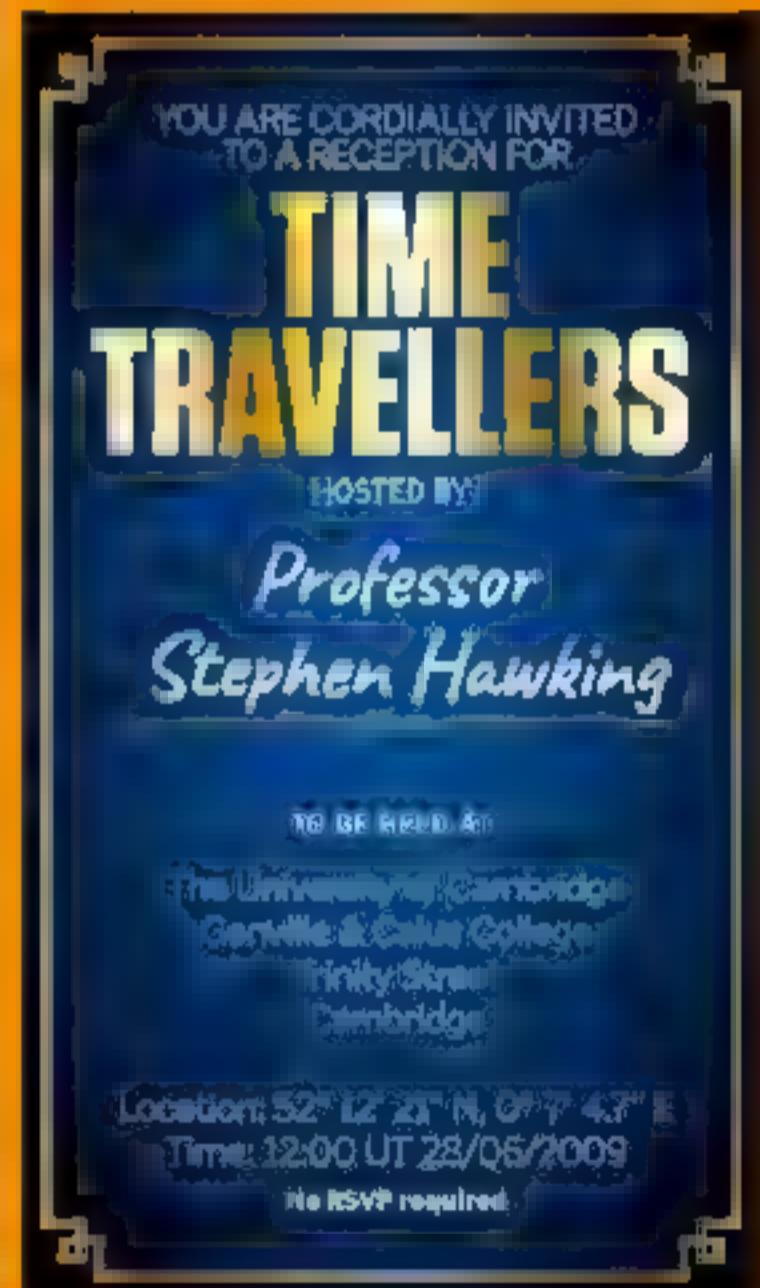
Yet as far-fetched as these things are in practical terms, there's no fundamental scientific reason – that we currently know of – that says they're impossible. That's a thought-

provoking situation, because as the physicist Michio Kaku is fond of saying – "everything not forbidden is compulsory". He doesn't mean time travel has to happen everywhere all the time, but that the universe is so vast it ought to happen somewhere at least occasionally. Maybe some super-advanced civilisation in another galaxy knows how to build a working time machine, or perhaps closed timelike curves can even occur naturally under certain rare conditions.

This raises problems of a different kind – not in science or engineering, but in basic logic. If time travel is allowed by the laws of physics, then it's possible to envisage a whole range of paradoxical scenarios. Some of these appear so illogical that it's difficult to imagine that they could ever occur. But if they can't, what's stopping them?

Thoughts like these prompted Stephen Hawking, who was always sceptical about the idea of time travel into the past, to come up with his 'chronology protection conjecture': the notion that some as-yet-unknown law of physics prevents closed timelike curves from happening. But it's only an educated guess, and until it's supported by hard evidence, there's only one conclusion we can come to: time travel is possible.

## A PARTY FOR TIME TRAVELLERS



## • 1941 • 1974 • 1992 • 2009

Two American experimenters, Herbert Ives and G.R. Stilwell, confirm the reality of time dilation by observing fast-moving particles inside a TV style cathode ray tube.

Physicist Frank Tipler designs the first real time machine (on paper at least). According to the design, a Tipler cylinder would use a string of rotating neutron stars to produce a closed timelike curve.

Stephen Hawking suggests that there might be an undiscovered law of nature that prevents closed timelike curves, therefore preventing time travel into the past from occurring.

Stephen Hawking holds a party for time travellers, which is widely publicised – but only after it has taken place. Unfortunately no time travellers turn up to the party.

# IT'S ALL RELATIVE

Long before Einstein in 1632, Galileo described the basics of relativity using tennis players on a ship

## Galileo's insight

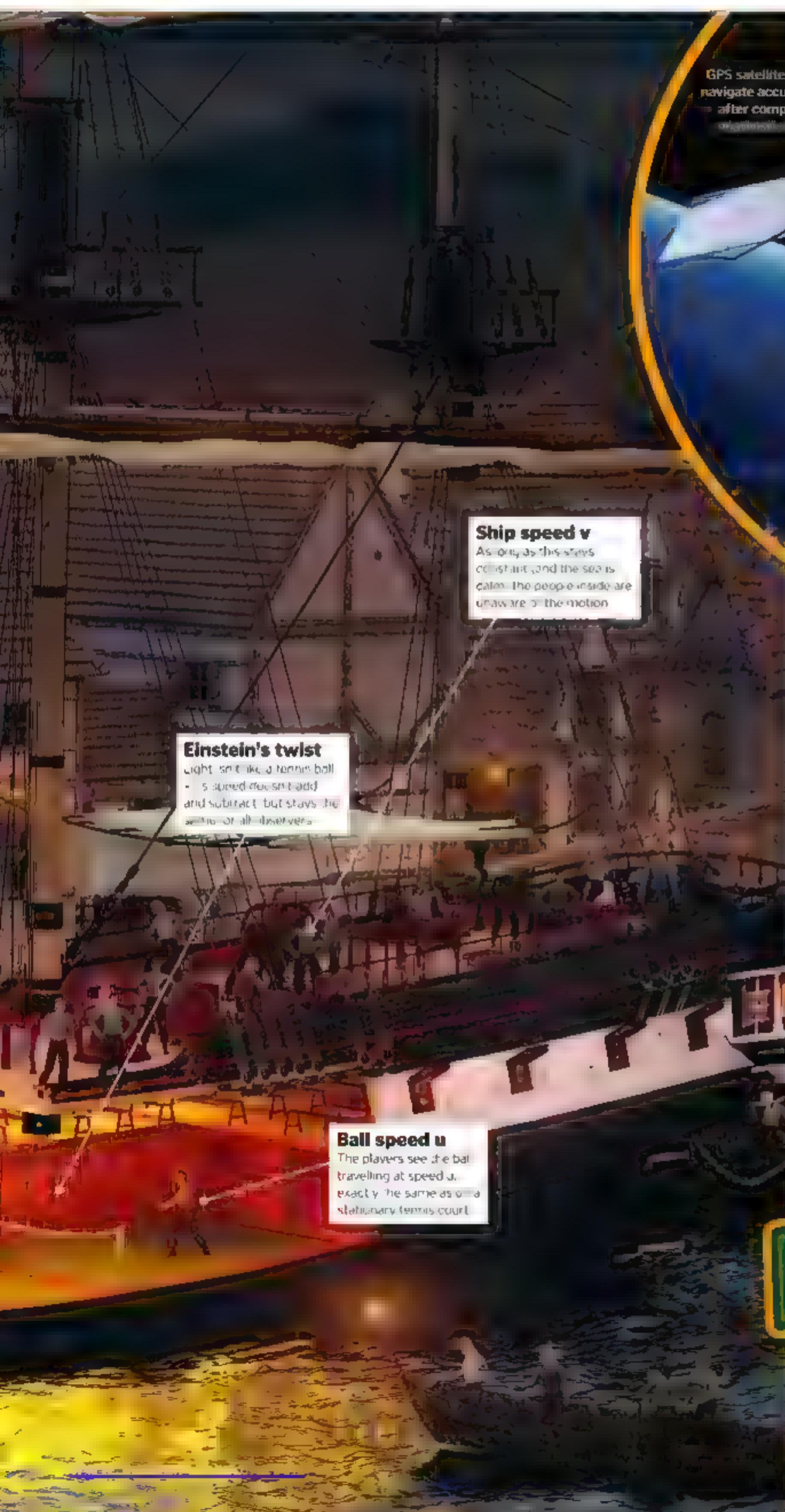
He realised the laws of physics work the same way whether you're stationary or in uniform motion

## Physics experiment

Any experiment on the ship (like this game of tennis) produces the same result as it would on dry land.

## View from the quayside

Galileo would see the ball travelling at speed  $v + u$  left to right or  $v - u$  right to left.



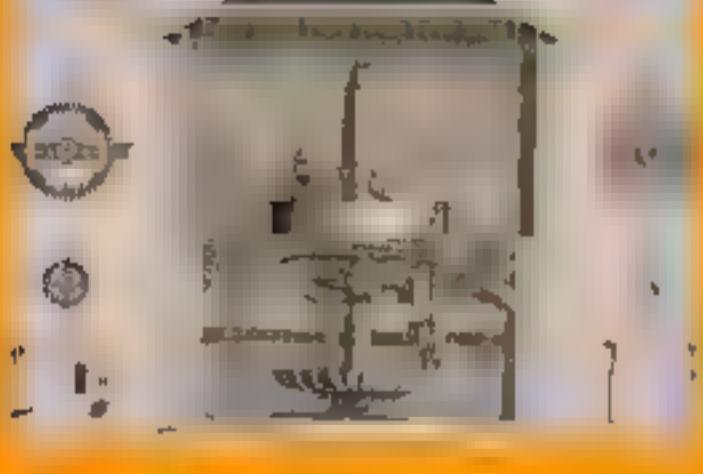
GPS satellites can help you navigate accurately, but only after compensating for the effects of time dilation

## THE ARROW OF TIME

One of the distinctive things about time is that it has a direction, a 'time arrow'. If you drop a cup of hot coffee left at room temperature it always cools down, it never heats up. Your umbrella always falls down when you use it, it never rises. These causal chains are examples of entropy, essentially a measure of the amount of disorder in a closed system. The total entropy of a closed system never decreases and this is the key factor determining the arrow of time. In 1907, James Clark Maxwell in the UK, first showed a distinction between past and future. In other branches of physics, like relativity or quantum theory, the momenta have a preferred direction. In one theory where time is arrowed, entropy is said to be zero in the past. Since, quantum systems, in which case particles have no memory, are not arrowed, the arrow of time is not absolute.

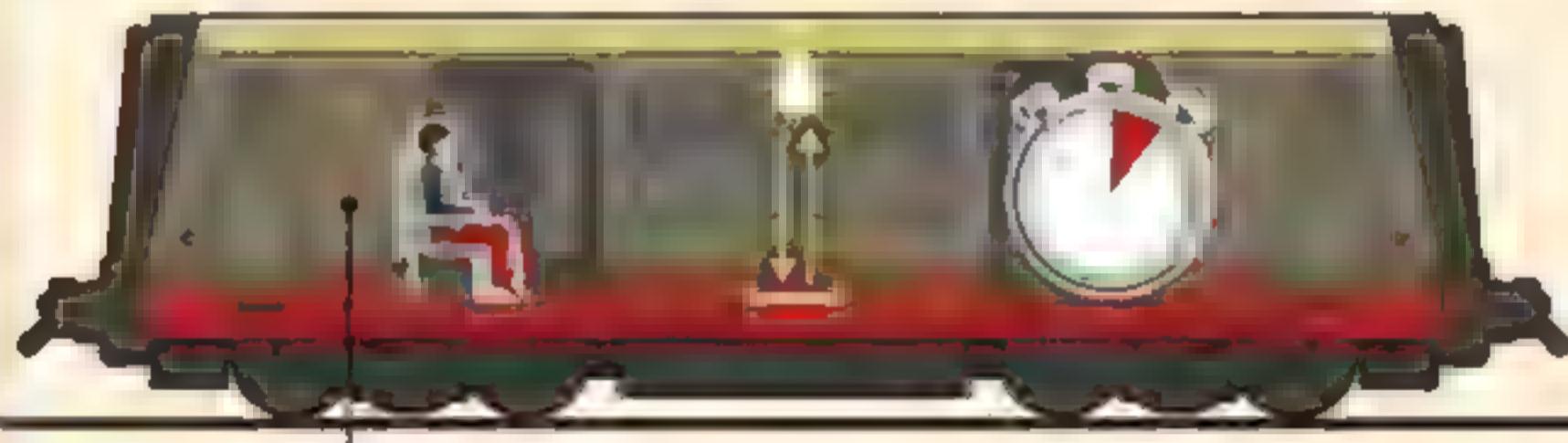


## TIME TRAVEL PARADOX



# THE RELATIVITY OF TIME AND SPACE

The fact that all observers measure the same speed of light has some odd consequences

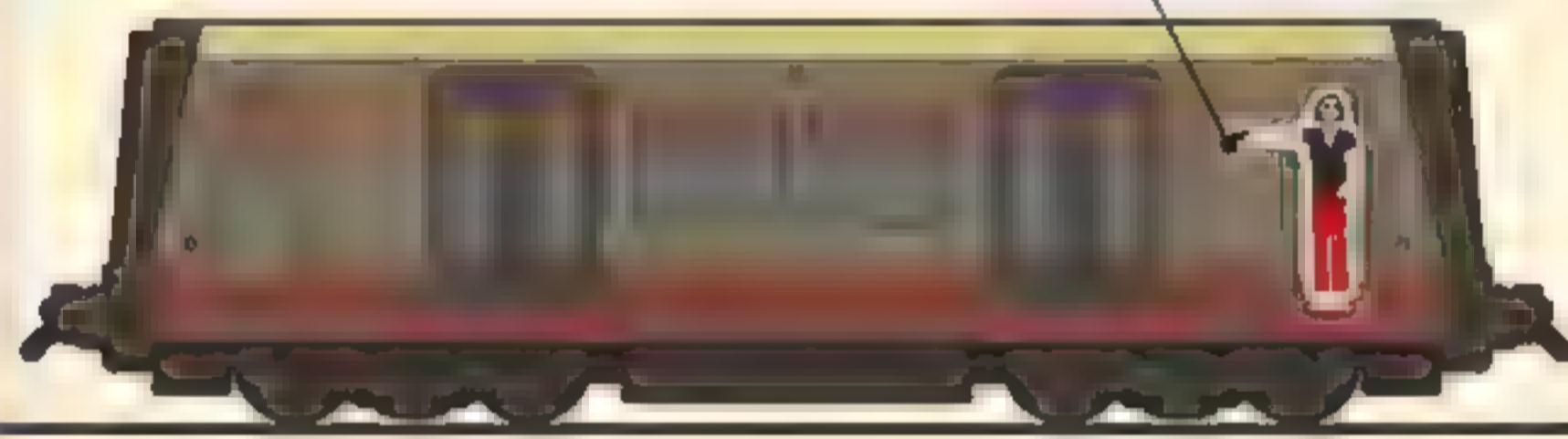


### 1 Experiment inside a moving train

Alice measures the time a beam of light takes to travel from the ceiling of the carriage to a mirror on the floor and then back to the ceiling.

### 4 Another experiment

Alice uses a laser rangefinder to measure the carriage length. This is the time the beam takes to travel to the end and back, divided by the speed of light.



## TIPLER CYLINDER

In 1974, the eminently respectable journal *Physical Review* published a paper by Frank Tipler that contained the first scientifically feasible design for a time machine. Sadly, although it doesn't break any laws of physics, Tipler's machine poses so many engineering challenges it would be impossible to build one in practice. The idea is to generate a closed timelike curve using a long, rapidly rotating cylinder of extremely dense material, of the kind found in neutron stars. These aren't quite as extreme as black holes, but they're still not easy things to manipulate. And to make a cylinder of the necessary length, at least ten of them would need to be brought together and lined up. This means that, just like wormholes, Tipler cylinders fall into the 'possible in theory, but impossible in practice' category.

## 2 The view from outside

Outside the train, Bob sees the light travelling a greater distance – but at the same speed. For him, the trip from the ceiling to the floor and back takes longer.



## 5 Bob's view

Seen from outside, the end of the carriage is moving towards the laser, so it takes less time to reach it. In other words, the carriage must be shorter.



## 3 Time is relative

Bob, as a stationary observer, sees events inside the moving train happening more slowly than Alice perceives them from the interior of the train.

## 6 Length is relative

Alice, moving with the train, sees it at its normal length. But to Bob, who remains stationary, it appears to have contracted along the direction of motion.

*"The idea is to generate a closed timelike curve using a long, rapidly rotating cylinder of extremely dense material, of the kind found in neutron stars"*



An artist's impression of a pair of neutron stars – a Tipler cylinder requires at least two

# What are eye floaters?

Discover what causes these optical oddities

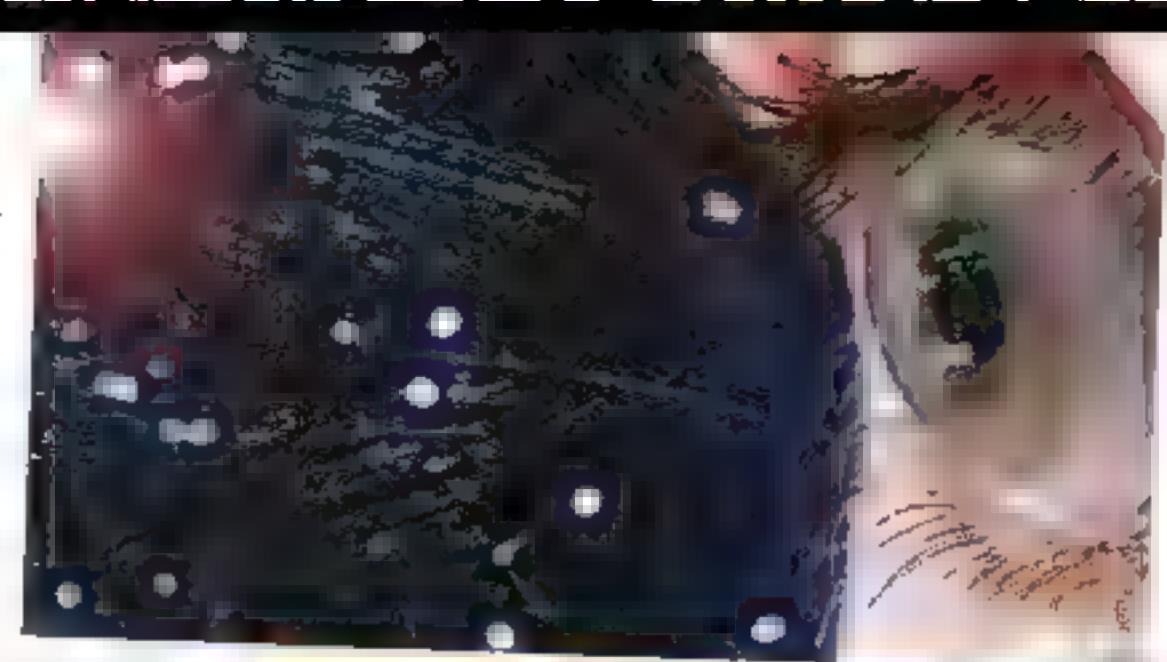
**G**azing up at clear blue skies can sometimes be interrupted by what appear to be bouncing squiggles of dust that evade our attempts to focus on them. These mysterious floaters are not specks on the surface of our eyes, but rather a part of the eye itself.

Filling the gap between the lens and retina is a pool of jelly-like fluid called the vitreous humour. As we age this eye jelly naturally begins to degrade and very slowly liquify. During this lifelong process, tiny 'clumps' break away and surf in the surrounding jelly. Known as vitreous floaters, they are most common in older people and those who are short-sighted.

Often unnoticed in day-to-day life, these floaters usually make an appearance when we

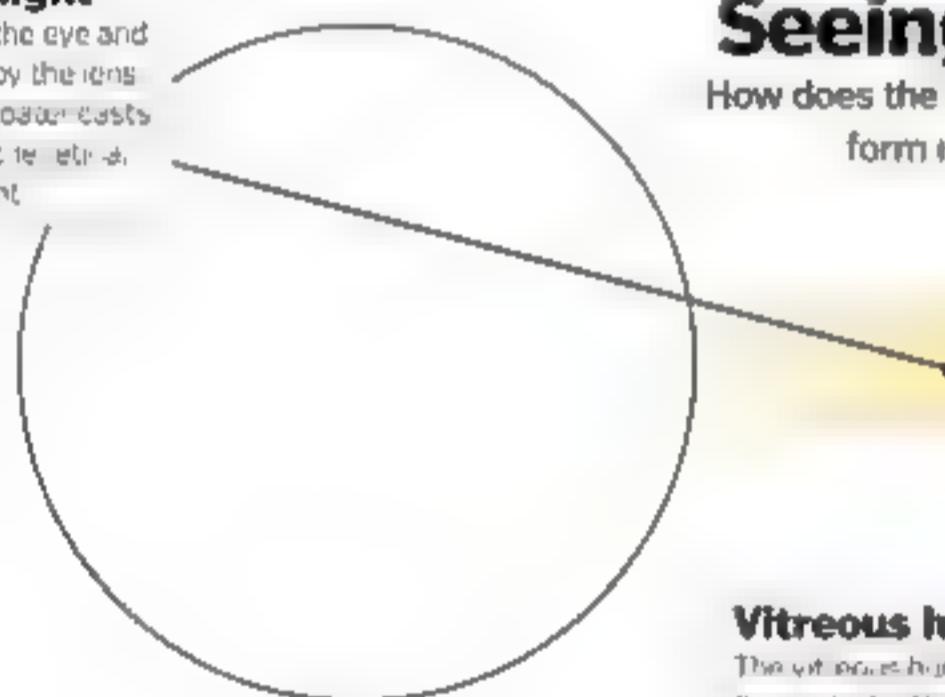
stare at a bright, blank canvas, such as a blue sky. As light enters the eye, these vitreous floaters obscure the light and cast a shadow over the light-detecting cells at the back of the eyes – the retina. When this communicates with the brain via the optic nerve, tiny lines of light are missing, so we see the floaters as shadows.

This biological shadow-puppet show is no cause for alarm in those that witness it. However, should the group of squiggles and wiggles increase dramatically then a trip to the optician may be necessary. This could potentially be a sign of retinal detachment, where the thin cellular lining tears and peels away from supporting blood cells, which can cause permanent sight damage.



## Incoming light

As light enters the eye and is focussed on by the lens, the obscuring floater casts a shadow over the retina, blocking the light.



## Clear vision

## Floater

By preventing light from reaching the retina, a silhouette of each floater is formed in our vision.



## Disturbed vision

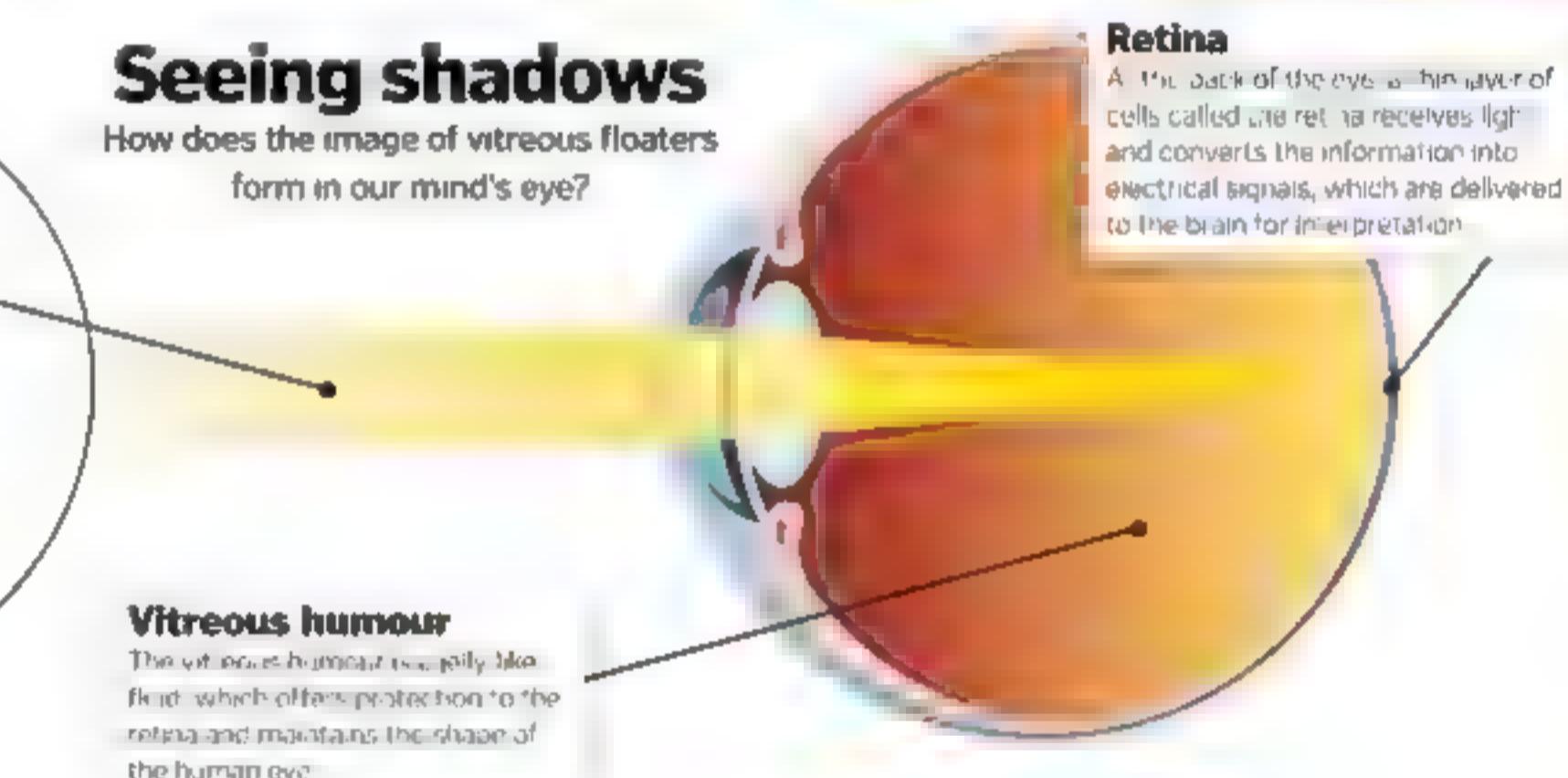
Retinal imaging can reveal the condition of the eye's retina and identify the likelihood of retinal detachment.

## Seeing shadows

How does the image of vitreous floaters form in our mind's eye?

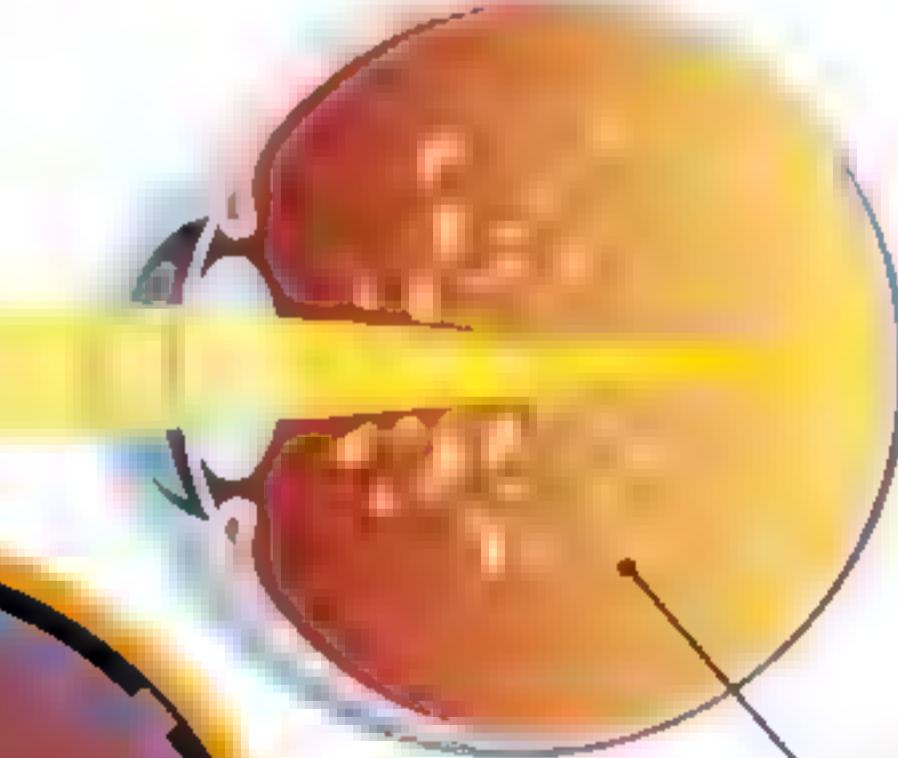
## Vitreous humour

The vitreous humour is a jelly-like fluid, which offers protection to the retina and maintains the shape of the human eye.



## Retina

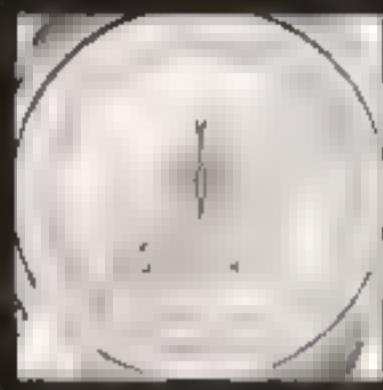
A thin back of the eye is a thin layer of cells called the retina receives light and converts the information into electrical signals, which are delivered to the brain for interpretation.



## Vitreous floaters

Over time, clumps of the protective fluid within the vitreous humour form and float around within the eye.

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# HOW TO CATCH A SPORTS CHEAT

Uncover the methods used by cheating athletes and the scientists who rise to stop them

Words by James Horton

In 1994, physician John Ziegler was meeting with a colleague from the Soviet Union. Both scientists were in the employ of their respective country's weightlifting teams, and at that moment in time the Soviets were ahead. They were just too strong. Ziegler pressed for an explanation, and his Soviet counterpart offered him one – his team had been using testosterone to build muscle mass, and the results spoke for themselves. Anabolic steroids had not yet been banned in professional competition, so Ziegler swiftly returned to his team and shared his discovery. Soon the US team, like the Soviets, were pumped full of doping agents.

This was an arms race in a very literal sense. But the US and the Soviet Union weren't the only two players. All over the world, in different sports, athletes turned to drugs to enhance their performance. The tide of doping would lead to one cyclist saying

that all he had to do was "follow the trail of empty syringes and dope wrappers" to stay with the pack during a race. Natural prowess had been shunned for artificial gains. The anti-doping agencies had to fight back; they needed new tests, and quickly.

Luckily the tests arrived. Today, the World Anti-Doping Agency (WADA) uses around 30 state-of-the-art laboratories that are equipped to screen for hundreds of doping compounds. They're able to detect anabolic steroids, stimulants, diuretics, narcotics, alcohol, synthetic oxygen carriers and more. Most of these tests are conducted using an athlete's urine. Blood is also screened, but urine is easy to collect – an athlete simply urinates into two containers: an 'A' and a 'B' sample, which is taken to the laboratory. The B sample (the back-up) can be stored in the freezer for over a decade if required, while the A sample is opened for screening.



Urine screening can be completed just 24 hours after starting the analysis

To prevent tampering with the urine during transit, the containers must be broken to be opened. If this occurs before it arrives in the lab, the B sample will have to be used. Once open, the urine's concentration is calculated before it is filtered, removing the unnecessary components of the liquid and leaving behind only the compounds the researchers are interested in assessing. A piece of equipment known as a mass spectrometer – which cleverly calculates the mass of compounds whizzing through it – is able to identify the majority of banned doping products if they are present.

For the trickier compounds, scientists use antibodies to bind to the prohibited compounds, which become visible on gels if they are in the sample. More still can be identified using a method known as SDS-PAGE, which shows the size of proteins as they are run

through a gel membrane. With all three techniques together, there is not much the scientists cannot find.

However, despite the technologies now available to governing bodies, the dopers haven't been fully deterred. Some still try to circumvent the tests, sometimes through ingenious methods. They attempt to use 'masking compounds', which disguise other performance-enhancing drugs from detection, and inject themselves with doping agents that quickly break down and are hard to capture in time. The hormone that controls the production of red blood cells, erythropoietin, falls into this latter category. Synthetically created erythropoietin has a half-life of just hours, but in that time it can stimulate the production of red blood cells that lasts for weeks.

To combat issues such as this, the UK Anti-Doping agency (UKAD) has implemented the Biological Passport programme. This involves the periodic collection and screening of an athlete's blood and urine, which are then recorded over time. If the athlete suddenly has a spike in a certain compound, the scientists can then begin to probe into the reason why. Has the athlete changed their training regime, or is something more sinister afoot?

Reinforced with the Biological Passport, dopers in regulated sports are very hard-pressed when trying to cheat.

But the anti-doping agencies of the world cannot relax. WADA's list of banned substances is updated each year, and dopers are constantly trying to find loopholes. Perhaps even more worrying are the new doping techniques appearing on the horizon. 'Neurodoping' has made headlines, as individuals voluntary electrocute parts of their brain in a bid to stimulate neurons. Some believe this may improve academic or athletic performance, but evidence for this has so far been lacking.

Gene doping, however, may represent a serious risk for the future. Despite gene editing still being poorly tested and highly dangerous in humans, WADA has already added gene-doping agents onto its list of banned substances. For a doper, the appeal is obvious. Why inject yourself with a booster of a banned protein molecule when you can have your DNA produce more of the molecule itself? If we do succeed in developing effective gene-editing

technologies to treat disease in the future, dopers may manipulate the technology for their nefarious needs. But you can be sure that the anti-doping laboratories will be there to catch them



## Twisting medication into doping agents

Although designed to help the sick, many medicines are abused as performance-enhancing drugs



Replacing the male sex hormone following testicular removal or in older men

Testosterone is important for muscle and bone development. It's been linked to weaker skeletal muscular systems and feminisation when natural production drops or stops in males. When taken on top of normal bodily production, synthetic testosterone can drive muscle growth above natural levels, unfairly boosting an athlete's strength gain



Alleviating nasal congestion and the tightening of airways caused by asthma

Stimulants such as ephedrine are appealing to doping athletes for two reasons. They can aid an athlete in boosting weight loss and they also boost available energy for the athlete during competition, partly by raising blood pressure and increasing blood supply.



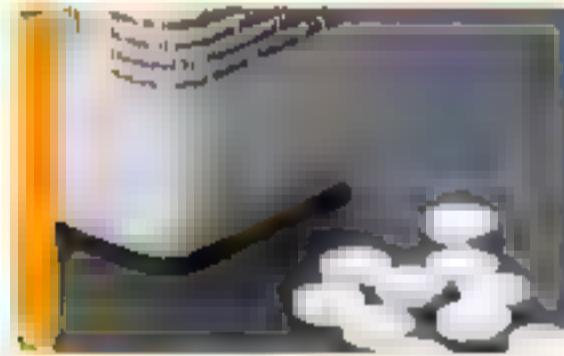
Lowering blood pressure, reducing tissue swelling and eliminating kidney stones

Sometimes known as 'water pills', diuretics affect kidney function and result in increased urine output. Athletes - who often have their urine screened for doping agents - can take diuretics to dilute their sample below detectable levels. Other athletes, such as boxers, use them to artificially lose water weight before a weigh-in



Regulating high blood pressure in individuals at risk of cardiac disease

Beta-blockers work to lower blood pressure by blocking the action of adrenaline - a hormone that increases blood circulation. This results in relaxed blood vessels and a slower heart rate, lowering the anxiety of athletes competing in sports such as shooting and archery, offering them a steadier hand



Treating breast cancer in men and women by blocking oestrogen receptors

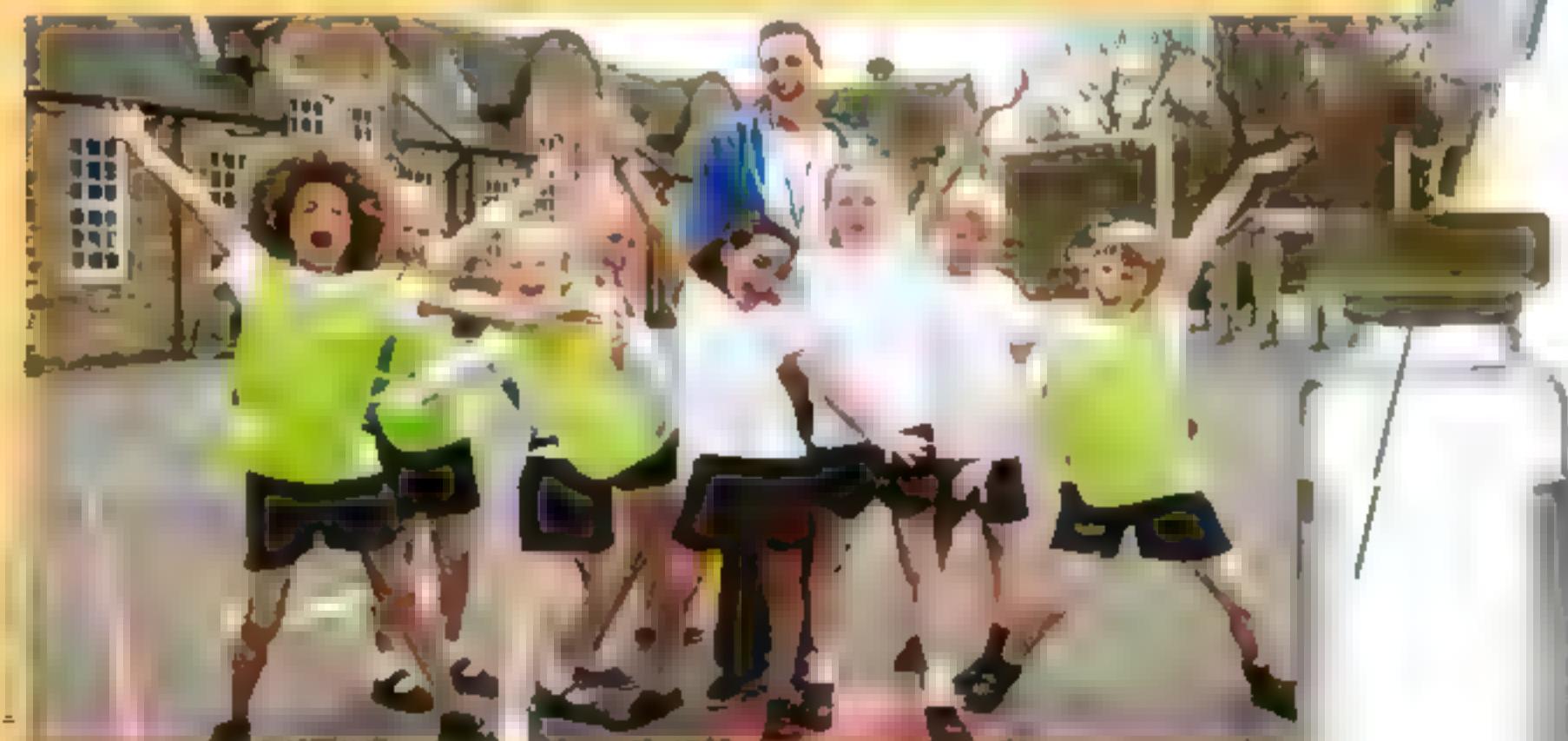
When an athlete dopes on testosterone, their body responds by increasing the amount of oestrogen production - a female sex hormone which can result in breast growth. Blocking oestrogen receptors with tamoxifen can help to keep this side-effect at bay, helping an athlete to continue cheating through testosterone doping



UKAD scientists at the King's College laboratory, London, can test for almost any banned substance

## Encouraging fair play

Testing athletes is incredibly important to ensure fair play, but another element in combating the use of doping agents in sport is through education. Since its inception in 2009, UK Anti-Doping has launched initiatives, starting with young children in primary schools through to teenagers, in a bid to inform about the risks of foul play and the benefits of fair play. The agency hopes to guide younger children into bonding with one another through fair competition and education in sportsmanship. Older children are also being educated on proper nutrition and the severe health risks involved in doping, encouraging them to not cut corners when chasing their first gold trophy or when training towards achieving their perfect physique.



UKAD has been involved in programmes on the benefits of fair play for children and young athletes

# Blood doping

How athletes can artificially increase their red blood cell count to improve their performance

## Increasing supply

Athletes increase their blood cell count either by transfusion or by injecting the hormone erythropoietin, which instructs the body to increase red blood cell production.



**1904**

Marathon-runner Thomas Hicks receives two injections containing the stimulant strychnine (plus some brandy) from his trainer during the race itself. Although extremely dangerous, he goes on to take home the gold.



**1928**

The International Association of Athletics Federations (IAAF) becomes the first sporting body to ban the use of doping agents for enhancing performance. The IAAF, however, is limited in its ability to enforce the new ruling. Instead it relies mostly on an honesty policy from athletes.



**1954**

A physician for the US weightlifting team learns that the Soviet Union team has been using testosterone to boost performance. The US team begins using anabolic steroids soon after.

## Timeline

**c. 700 BCE**

At the ancient Greek Olympic Games, athletes are encouraged to consume sheep testicles, which contain testosterone as a means of boosting strength.



## Deposit

The athlete has at least half a litre withdrawn weeks before a competition. Their body will naturally restore the lost red blood cells.

## Separation

A piece of equipment known as a centrifuge then spins the blood at high speeds, forcing the red blood cells to the bottom of the tubes

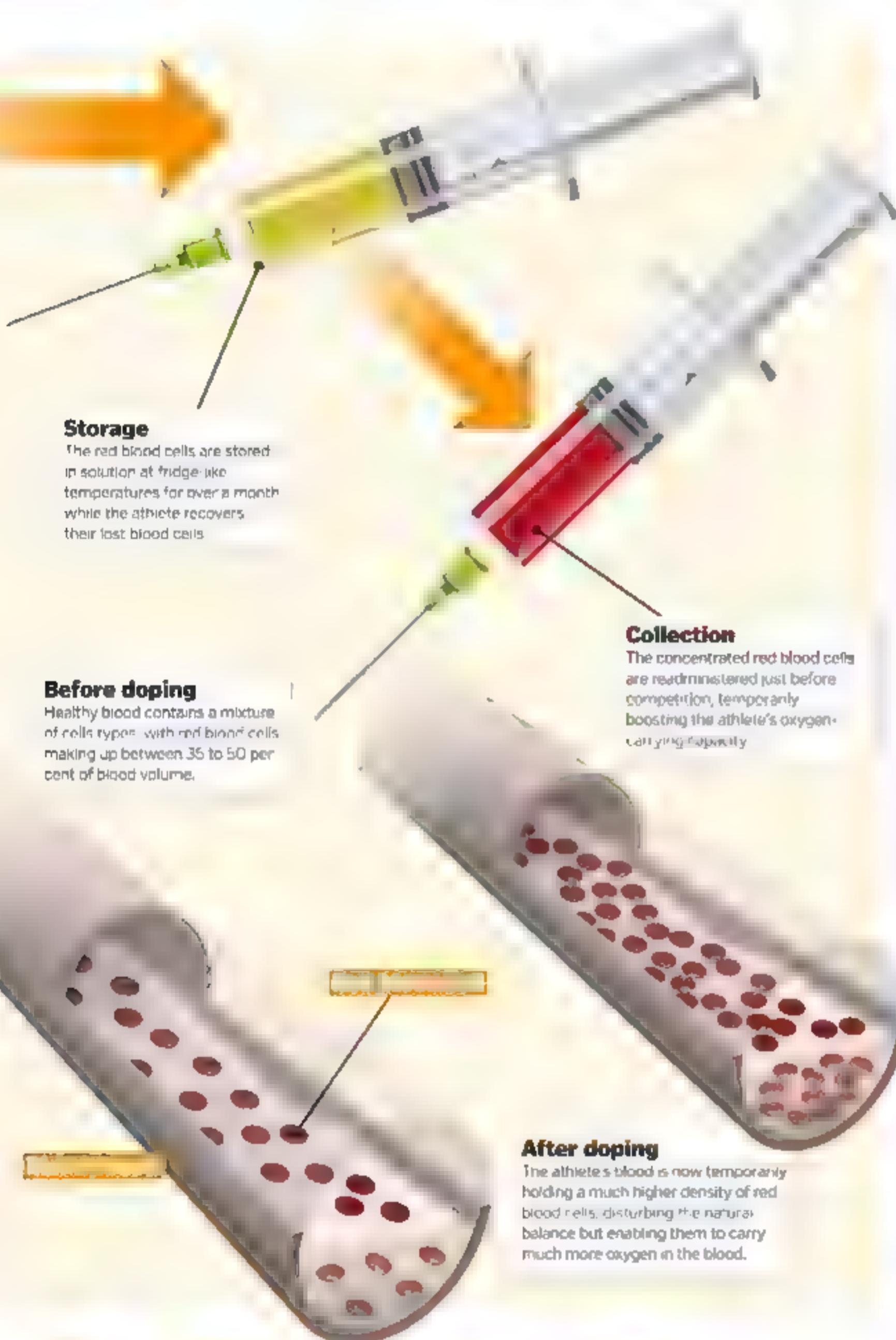
## Plasma

The heavy oxygen-laden red blood cells clump at the bottom of the tubes, while the remaining liquid is drawn off and returned to the athlete.

**"Our job is to catch the people who are cheating, but it's also to protect the people who aren't"**

**1960**

Danish cyclist Knud Enemark Jensen dies during the Rome Olympic Games after taking amphetamine (a stimulant) and Roniacol (a blood vessel dilator).

**Storage**

The red blood cells are stored in solution at fridge-like temperatures for over a month while the athlete recovers their lost blood cells.

**Before doping**

Healthy blood contains a mixture of cell types, with red blood cells making up between 35 to 50 per cent of blood volume.

**Collection**

The concentrated red blood cells are readministered just before competition, temporarily boosting the athlete's oxygen-carrying capacity.

**After doping**

The athlete's blood is now temporarily holding a much higher density of red blood cells, disturbing the natural balance but enabling them to carry much more oxygen in the blood.

## QA Finding foul play

We speak with Dr Alan Brailsford, head of UK Anti-Doping's laboratory

**How many athletes' samples are analysed in the lab every week?**

It can vary a lot depending on what sporting events are happening. The summer tends to be quieter, but you can get big events that cause a spike in the number of samples. There's a bit of fluctuation, [but] on average we look at between 200 to 250 samples every week of blood and urine – most of that will be urine. Overall last year we screened around 13,000 samples.



**Certain compounds have narrow detection windows. Does this make them the hardest to track?**

They do present a challenge, and that's one reason why our work is helped by UKAD's Intelligent testing, which looks at the most likely time athletes are going to dope. It'll look at an athlete's training and competition schedule and ask, if you were a doper, when would be the most likely time to take it? So while we may have a narrow window, we can maximise our opportunity by selecting the best time to test. The lab's job then is to work on extending the detection window.

**Has working in this field reduced your ability to enjoy competitive sport?**

I haven't grown cynical in any way. I don't watch sport with a cynical eye because I know the vast majority of results come back negative and the vast majority of athletes are clean. Our job is to catch the people who are cheating, but it's also to protect the people who aren't and create a fair sport.



**1964**

Anabolic steroid use becomes ubiquitous at the Olympic Games and in other sports, including bodybuilding.



**1988**

100m sprint Olympic champion Ben Johnson is stripped of his gold medal for doping. His prize is handed over to runner-up Carl Lewis, who keeps the medal despite also failing a drug test.



**2012**

Seven-time Tour de France-winning cyclist Lance Armstrong is stripped of all titles received since 1998 after drug and blood doping.



**2015**

Russian athletes are banned from international competitions after evidence emerges of state-sponsored doping cover-ups.

© reserved  
bodies are stored together in  
special 'sleeping bags' in this  
supercooled container

# Keeping cold to live forever

Cryonic preservation relies on the science of the future to cure disease and even cheat death

**T**he concept of death is difficult and frightening for many, and the search for immortality dates back centuries. From alchemy and the elixir of life to spending eternity as a cyborg, people have dreamed up numerous schemes for evading the inevitable. One approach that claims to have a scientific foundation is cryonics – the preservation of human bodies by freezing or deep cooling (known as vitrification).

Cryonics takes place after a person is legally dead. Their body or head is frozen and stored indefinitely in a chamber, in the hope that scientists in the future will discover ways of bringing them back to life, reversing any damage caused by the preservation process and curing the disease or condition that caused their death. Cryonics believe that, as long as death was not caused by trauma and the brain remains

intact, technology yet to be invented will allow full revival; suggestions for this future technology include cloning, nanomedicine and copying the mind onto a computer.

Storing frozen bodies was first proposed in 1962 in Robert Ettinger's book *The Prospect Of Immortality*. In 1967 Dr James Bedford, a retired psychology professor, became the first person to be cryonically frozen. Since then around 400 people have joined him in suspension, and it's estimated that 3,000 people around the world have plans to be frozen and stored rather than buried or cremated. Four facilities offer cryonic preservation – one in Russia and three in the US.

Despite a number of fierce supporters, cryonics is largely regarded as a pseudoscience, with the practice denounced by the majority of the scientific community and facilities accused of giving false hope.

**"Their body or head is frozen and stored indefinitely in a chamber"**

Cryonics response teams practise on a dummy, training to prepare bodies as quickly as possible



## Cryonic cooling process

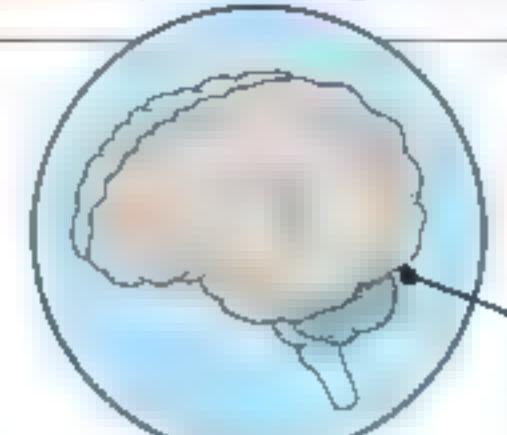
Preparation for storage needs to be fast and immediate

### Rapid response

The cryonic freezing process must begin as soon as a person is declared clinically dead.

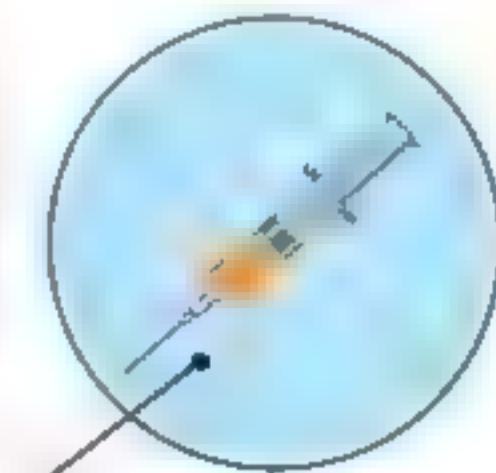
### Inverted

Bodies are stored upside down so that their brains remain preserved in liquid nitrogen if the tank leaks



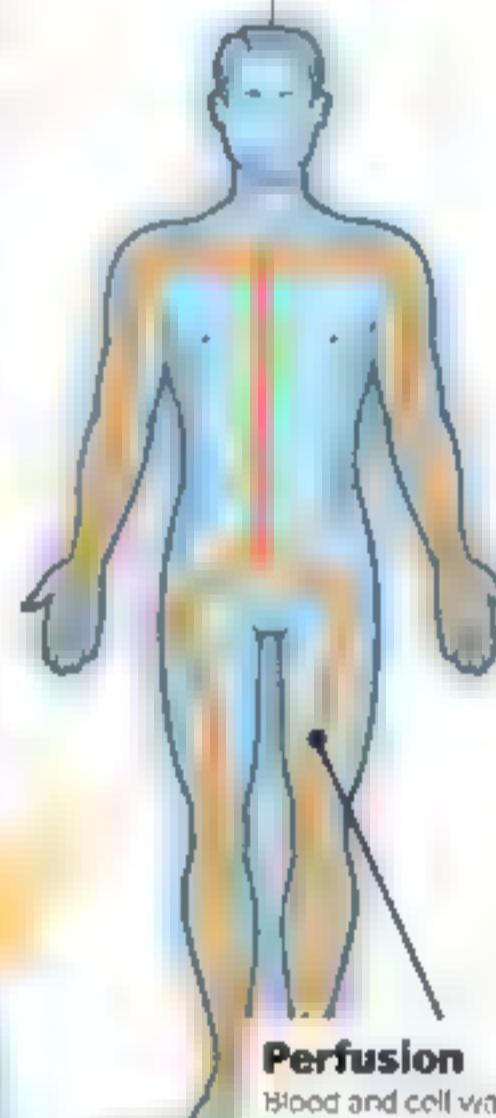
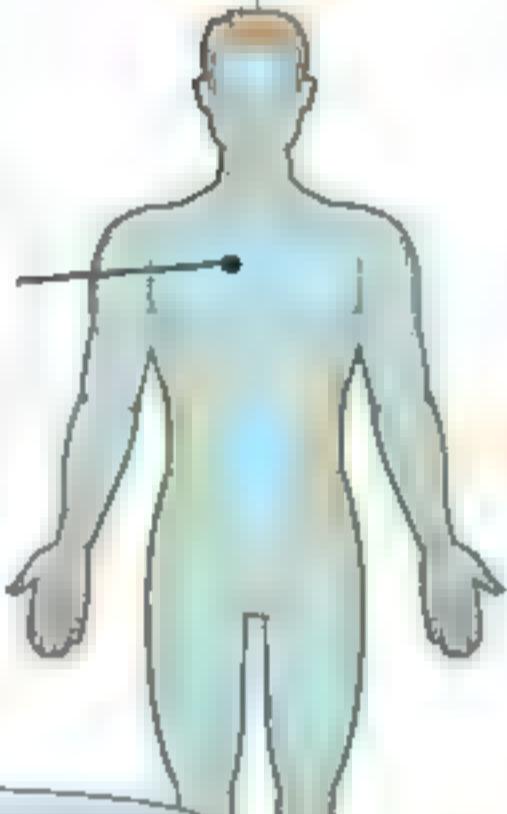
### Stabilisation

A specially trained response team stabilises the body and performs CPR to maintain oxygen flow to the brain



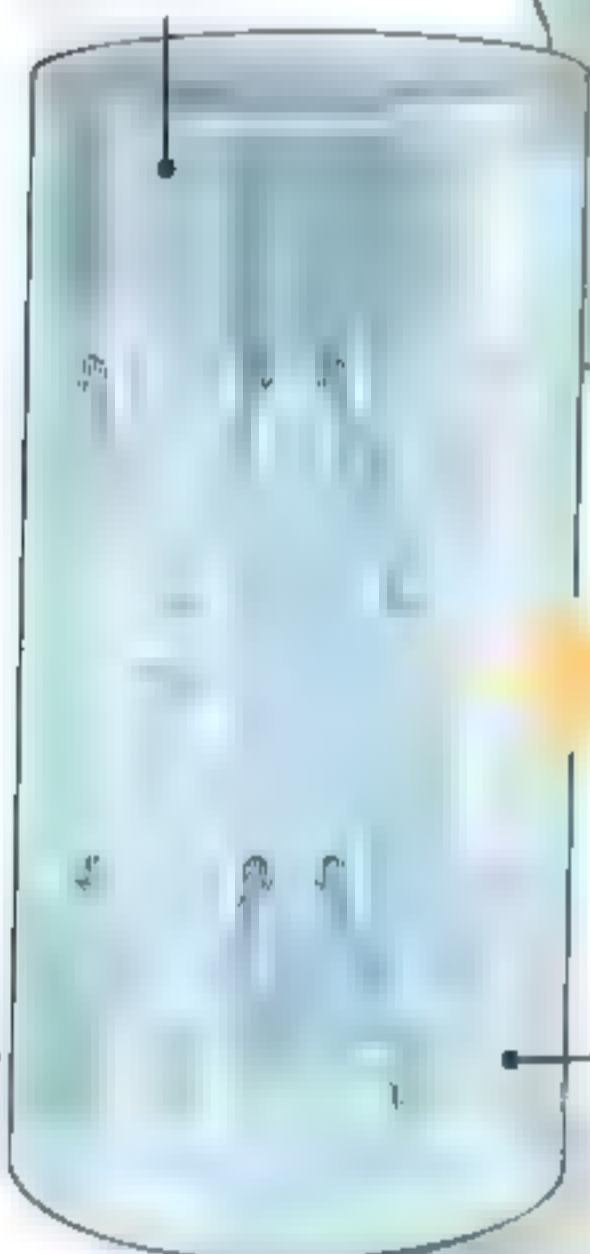
### Cooling begins

The body is put on ice to start the cooling process and an anticoagulant injection stops the blood from clotting.



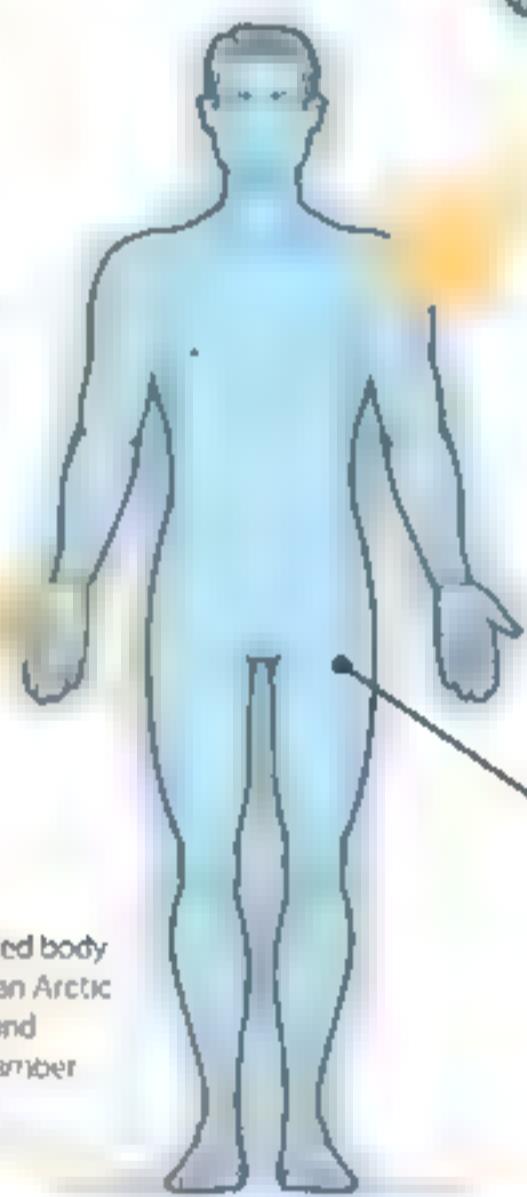
### Perfusion

Blood and cell water are drained out and replaced with cryoprotectant, an anti-freeze intended to prevent ice crystal damage



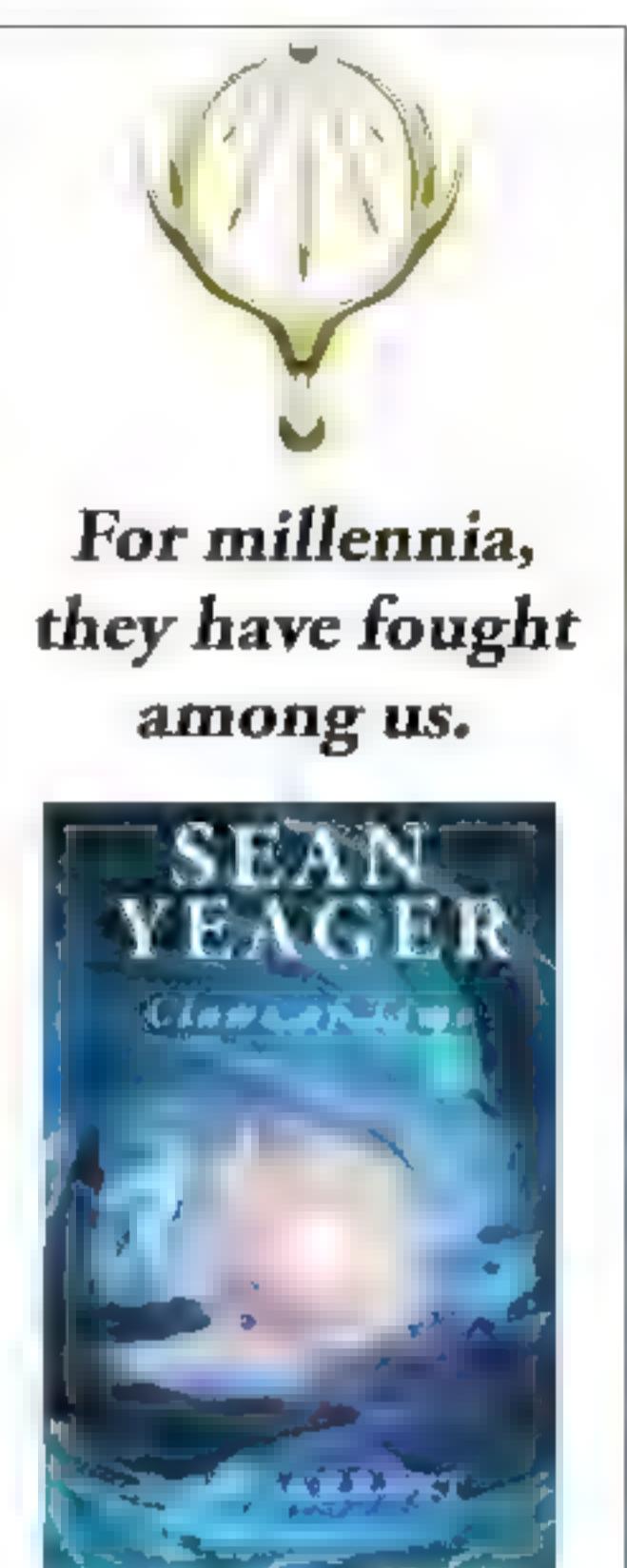
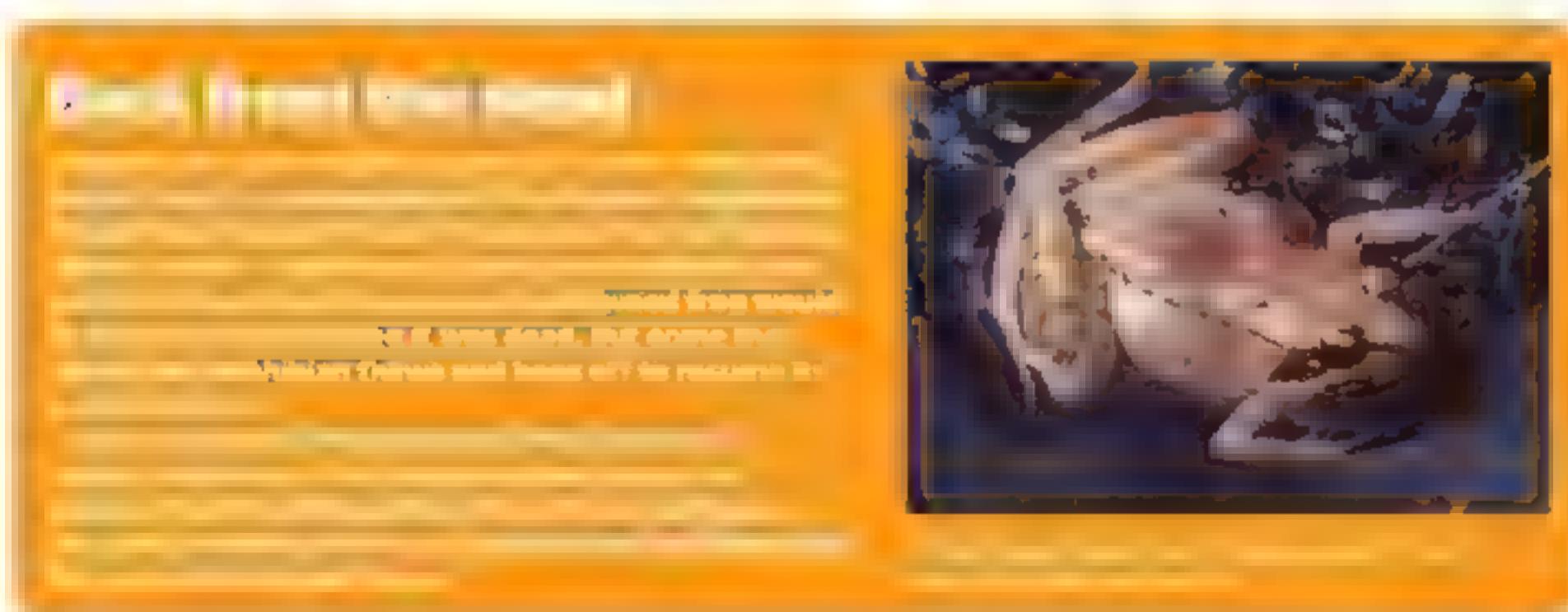
### Storage

The supercooled body is placed into an Arctic sleeping bag and stored in a chamber kept at -196°C

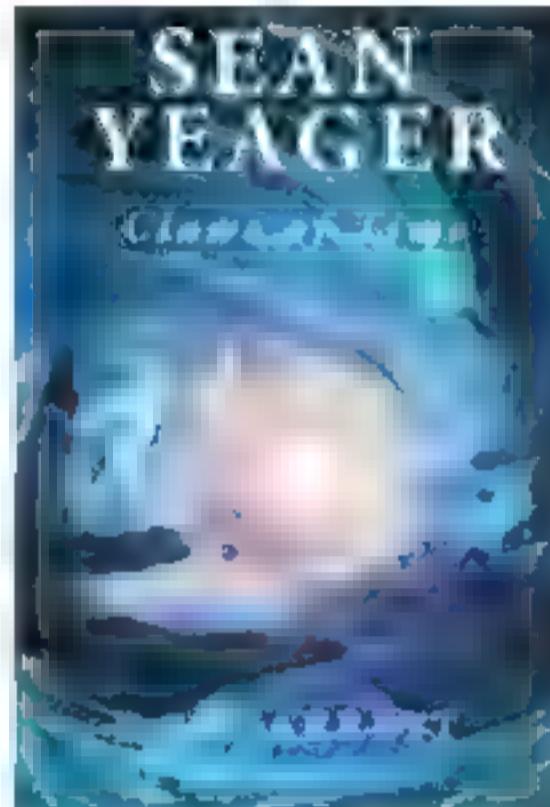


### Supercooling

Once prepared, the body is cooled to around -130°C using dry ice



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# All aboard HMS Enterprise

See inside this Royal Navy ship and discover how it surveys the seafloor

Words by Scott Dutfield

**B**erthed in London's financial district, HMS Enterprise (H88) seemed out of place between the skyscrapers of Canary Wharf. It's also an unusual ship for the Royal Navy, as this vessel is not built for battle but to scan the ocean bed.

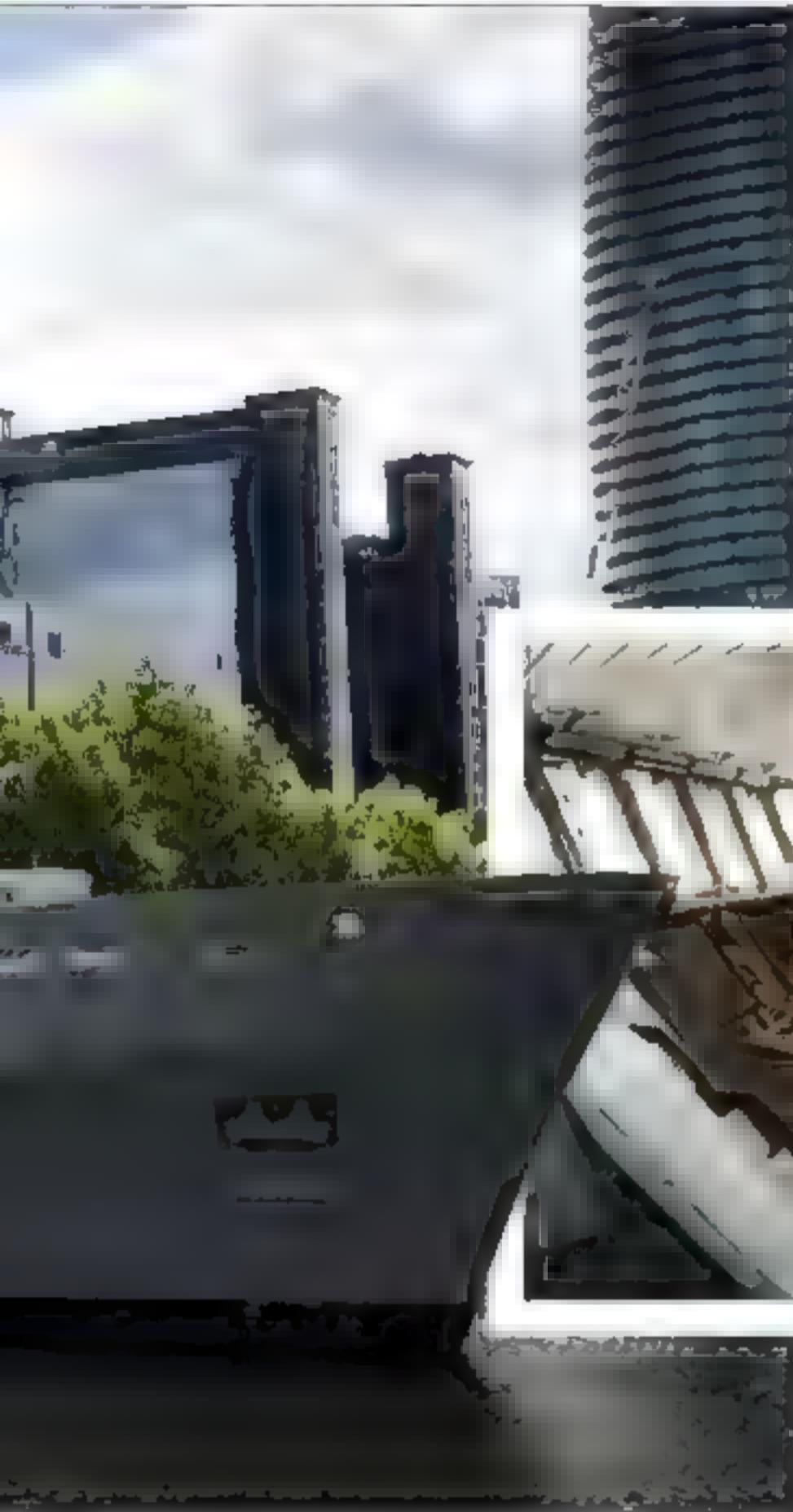
Our journey around the insides of Enterprise revealed it to be compact, as was the gangway to the deck of the ship. Filled with a network of narrow corridors, the bowels of the ship form a military maze, filled with the hustle and bustle of its 50 crew members. The ship's total workforce is a company of 80, split into three watches, each rotating every four to five weeks.

Everyone aboard Enterprise plays a key role in its maritime functions – from navigation, engineering and communications, to analysing the vital information gathered from the ship's sonar technology. The principal role of this ship is to gather data and information from below the waves. Using a multibeam echosounder, a type of sonar, officers and ratings aboard HMS Enterprise are able to construct highly accurate 3D models of the seafloor.

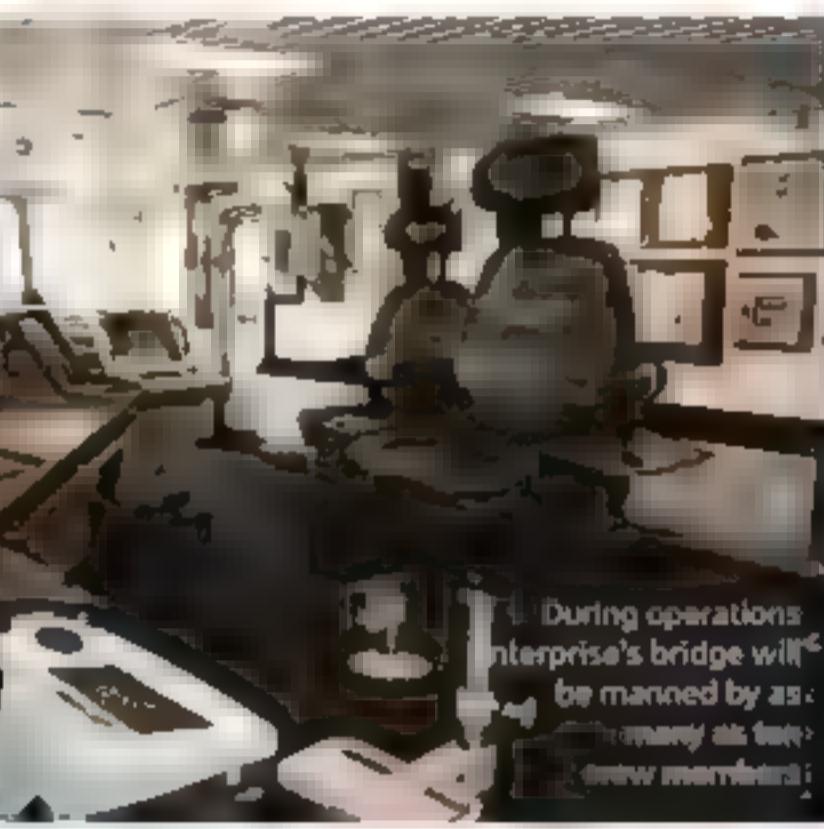
Similar to the way bats use echolocation, the sonar emits soundwave pulses, known as a ping, to a depth of around 1,000 metres. Once the soundwaves reach dense material below the sea,

such as rock, the waves reverberate back towards the ship in the form of echoes. Once the echoes are received by the sonar, the time taken to receive the waves following transmission is calculated and the depth can be determined. As a multibeam sonar, hundreds of points are collected and recorded, as opposed to a single-beam sonar, which only determines the depth at a single point. As Enterprise moves through the waves the sonar continually sends and receives soundwaves, which can be used to generate a corridor model of the seafloor.

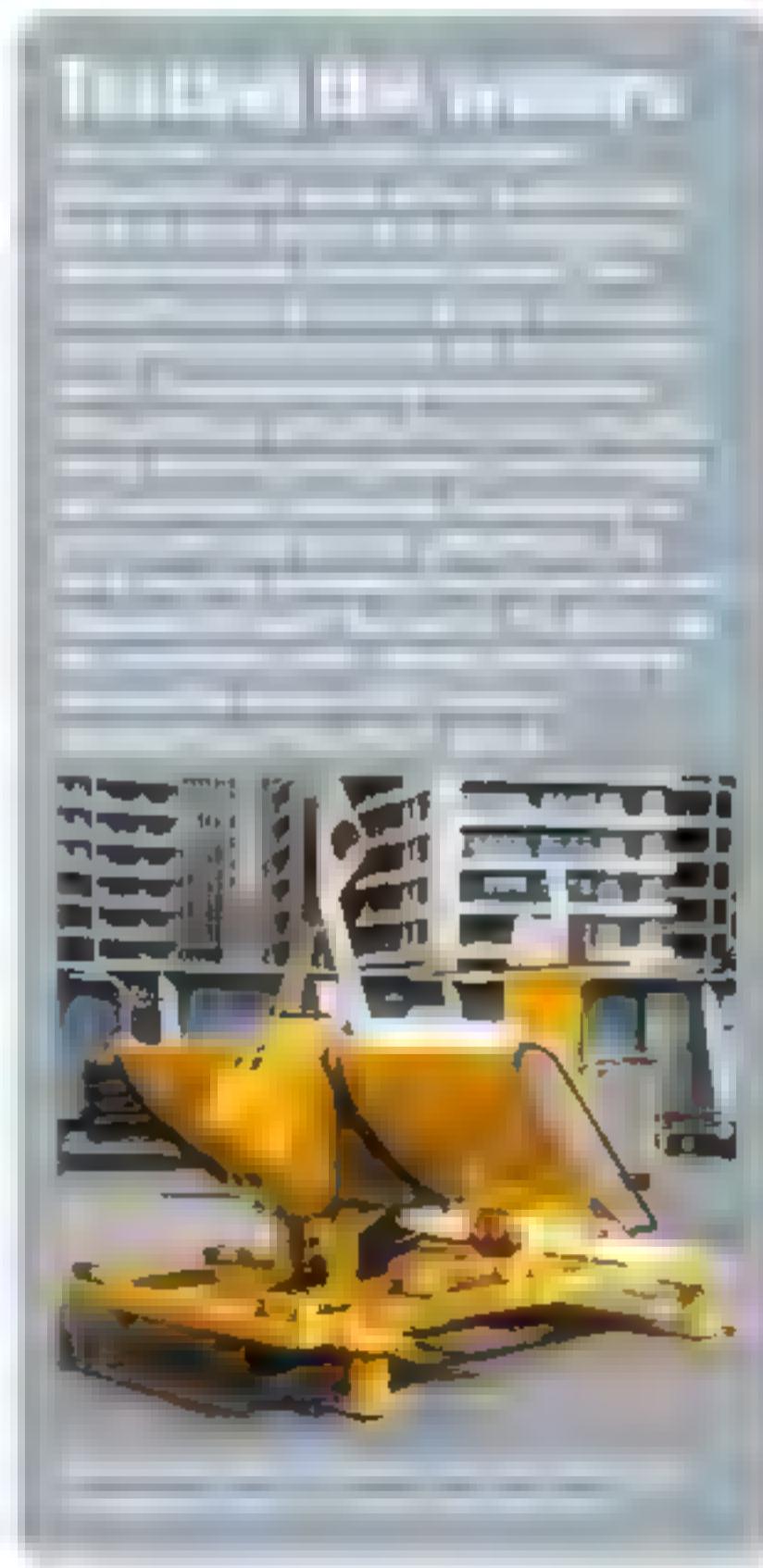
Receiving instructions from the UK Hydrographic Office, Enterprise and its crew will



Side-scan sonar is used to get up-close and personal with objects on the seafloor



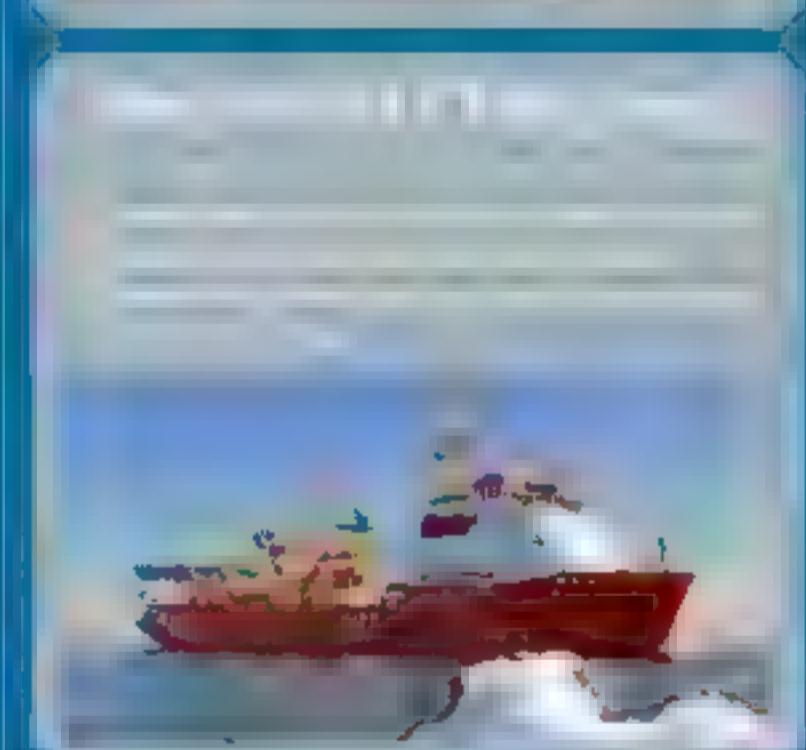
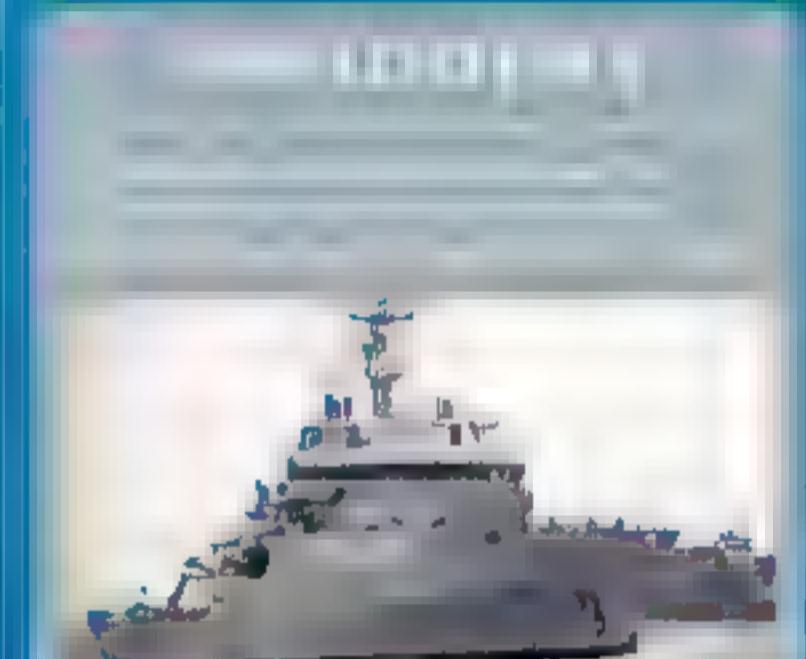
During operations, Enterprise's bridge will be manned by as many as 100 crew members



undertake a variety of tasks while out at sea. Frequently it is the ship's mission to assess pathways along the sea for other ships seeking safe passage. The maps generated from the multibeam sonar allow other ships to avoid any geological structures that might impede their journey. Across the Pacific Ocean, survey ships also play a vital role in understanding the depth and breadth of submarine volcanic activity. In known locations of a new or recent eruption, ships such as Enterprise are able to monitor the activity to assist the movement of other navy vessels, such as submarines.

To get an even better picture of what lies on the seabed, additional sensory equipment called side-scan sonars are cast overboard and towed as the ship moves. Operating in a similar way to the ship's multibeam sonar, side-scan sonars are lowered hundreds of metres into the water, where the echoes of emitted sound are recorded. This close-contact sonar gives navy personnel the chance to gain a clearer image of what's below them. These torpedo-shaped sonars are also an excellent method of locating historical shipwrecks and, more importantly for the safety of shipping, any unexploded ordnance or mines that may be lurking deep below.

## SURVEY SQUAD





Though it's not designed primarily to engage in conflict, Enterprise is still equipped with two large 20mm cannons

## Between decks

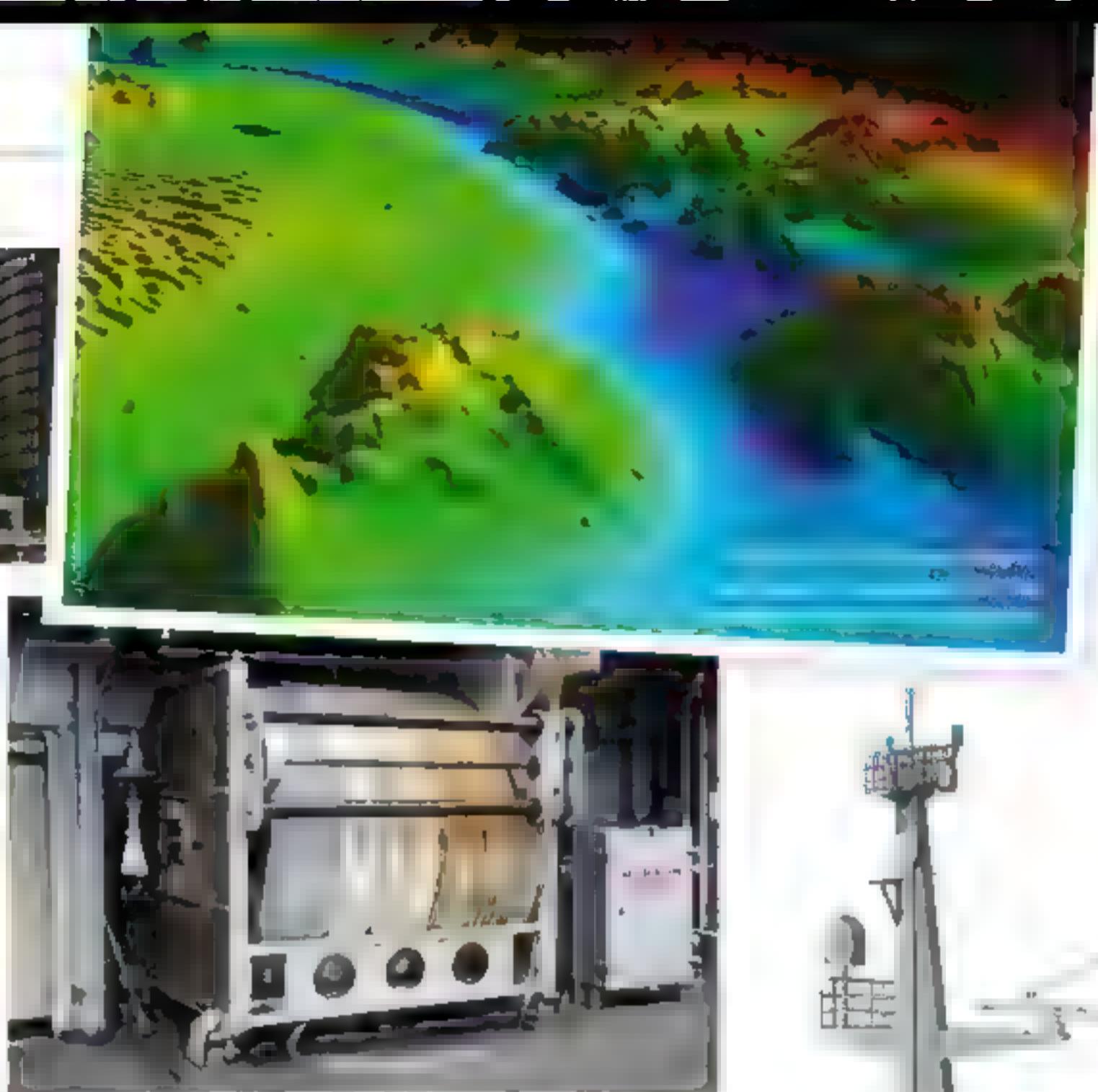
What makes HMS Enterprise such a good survey vessel?

### Sonar winch

Much like casting a fishing net, side-scan sonars are released into the water at the end of a line and reeled back in once the survey is concluded

### Deck crane

HMS Enterprise uses a deck crane to launch a multi-beam survey unit - a motorboat called Spratline - to access remote areas



Side-scan sonars are released into the water via a large winch

### Survey room

Data collected from the multi-beam sonar and side-scan sonars is analysed in the survey room, and maps are produced for future use



### Azimuth thrusters

High-power propeller engines move the heavy load of Enterprise, which has travelled over 80,000 kilometres since its launch

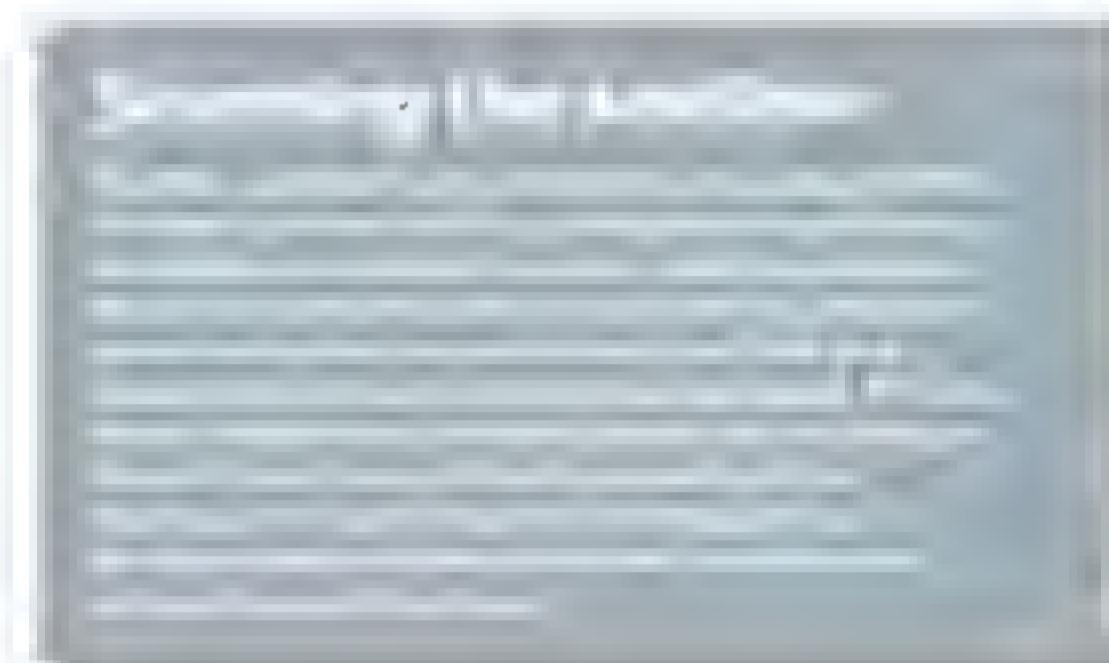
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### Communications

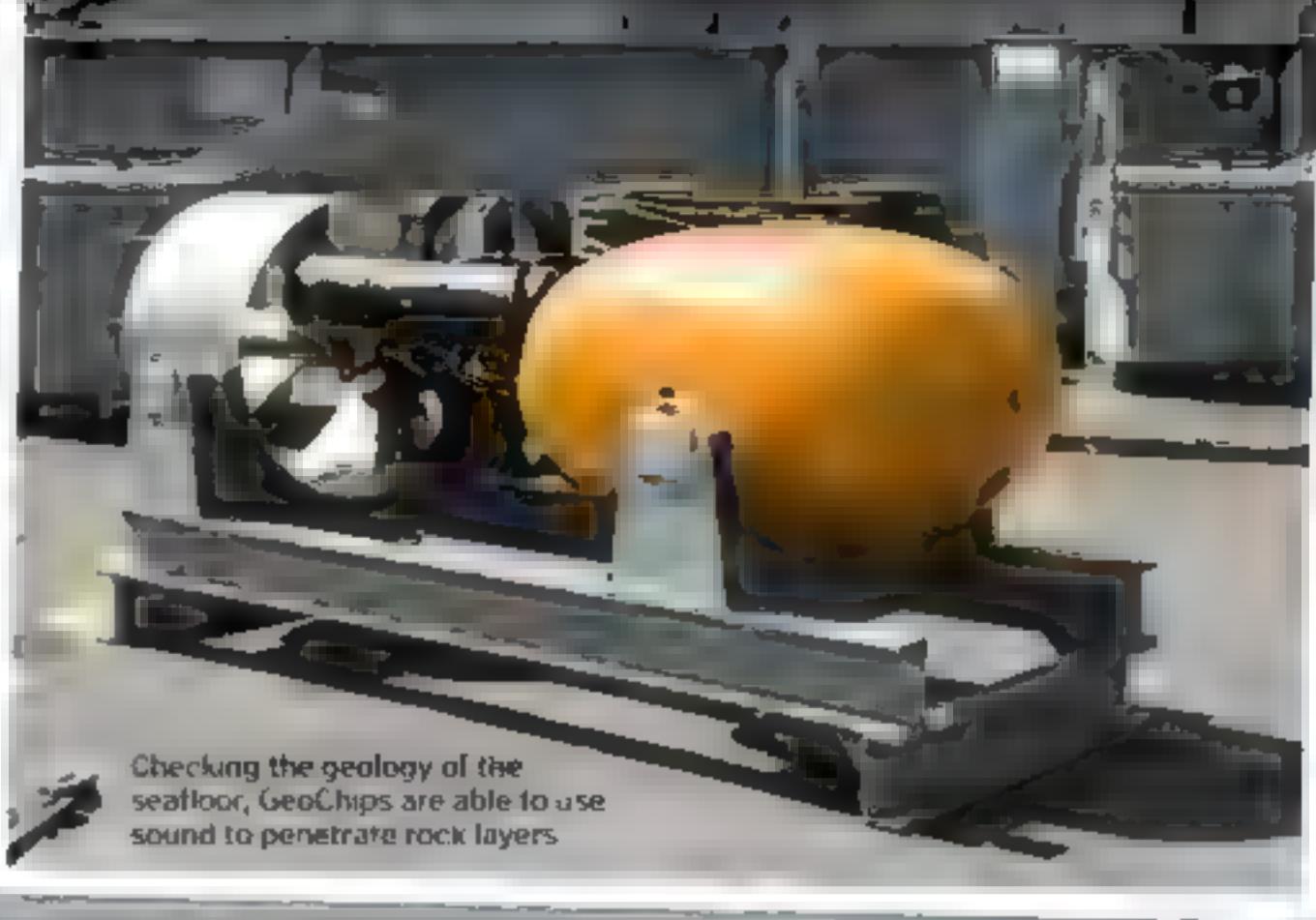
Radar and satellite GPS enable Enterprise to pinpoint its exact location, which is vital for creating maps of the seafloor

### Bridge

The bridge is where the brains behind the operation reside. Here the captain and the navigation personnel monitor and control the ship's movements

### Weaponry

Although technically a warship, Enterprise is apathetic on the weaponry front, with only two 50mm cannons and three Mk.44 missiles on deck



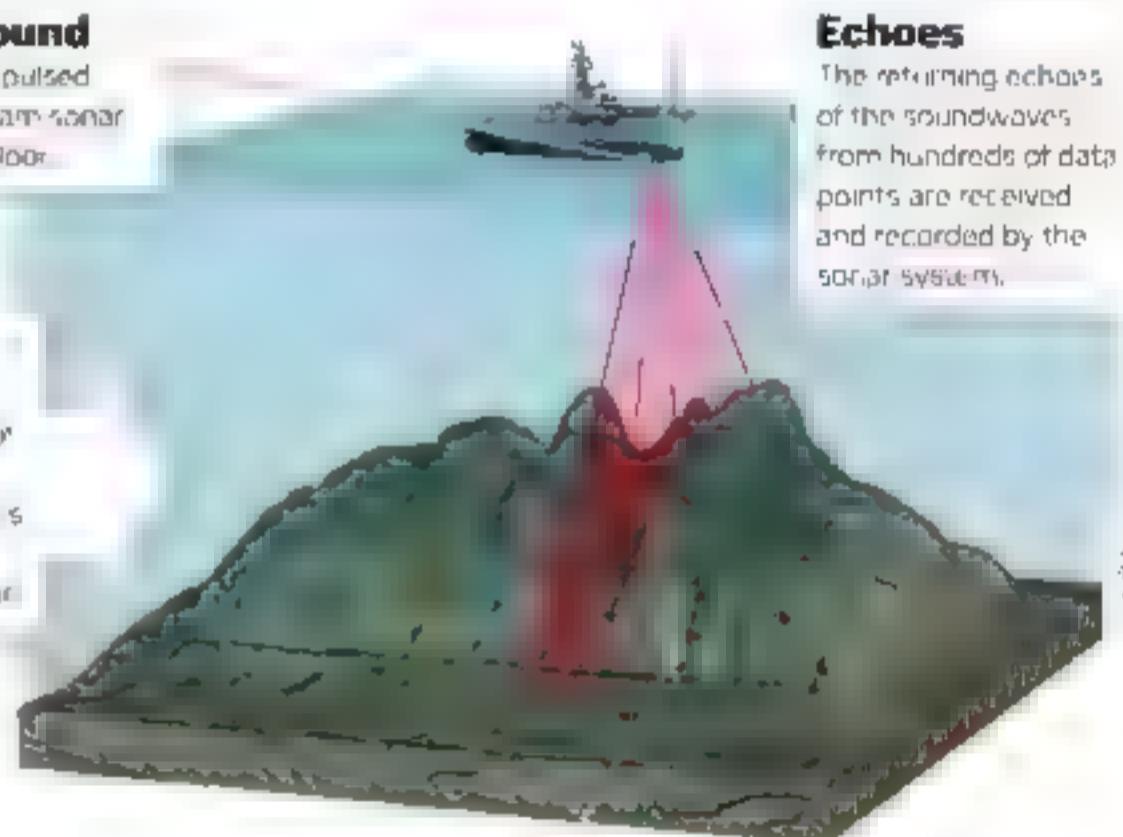
Checking the geology of the seafloor, GeoChips are able to use sound to penetrate rock layers

### Emitting sound

Soundwaves are pulsed from the multibeam sonar towards the seafloor

### Multibeam echosounder

Mounted on the keel of Enterprise is a multibeam sonar that is used to create 3D models of the seafloor



### Echoes

The returning echoes of the soundwaves from hundreds of data points are received and recorded by the sonar system

### Seafloor

Based on the speed the echoes are received, a three-dimensional map can be created to depict the seafloor topography

H88

1770

1848

1926

1958

2003



# How electric aeroplanes work

Inside the aircraft that's leaving smaller carbon footprints in the sky than hi-octane jets

**R**ight now, there are an estimated 20,000 aeroplanes in use around the world. Around 3 billion people travel on these planes, which account for four per cent of all greenhouse gas emissions. By 2040 it is thought that there are going to be more than double this number in use.

To control the impact this could have on the Earth's climate, electric aircraft are providing a more sustainable solution to air travel. Electric engines have been designed in an attempt to create an emission-free air industry. In today's connected world, there is a growing demand for air travel, so work needs to be done quickly to counteract the potential damage this demand could have on the planet.

Electricity can be used to power electric aircraft in a variety of ways, including batteries, ground power cables, solar cells and power beaming. Power beaming involves the wireless delivery of energy to the aircraft from a remote power plant: the most common methods of this are through microwaves or lasers.

Electric travel was previously regarded as a dream for the future, until encouraging progress began to be made. In 2016, Solar Impulse 2 brought the electric dream further into reality. The electricity-powered aircraft was the first of its kind to complete a trip around the globe, in a journey that took a full 16 months. During this time no fuel was burned. It was a zero-emission trip.



**5 STAGES**

## Flying locally

There is a big demand for small electric planes: 2 billion tickets are sold each year for flights shorter than 800 kilometres.

## Centuries of progress

Although the use of electric-powered aircraft is on the rise, the invention is not new. This type of flight was first tested in the 1800s.

## Limited distance

It may be a long wait before you can fly from the UK to Australia, electrically. The current drawback in e-aircraft advancement is its use for long-haul flights. This is due to aircraft size.

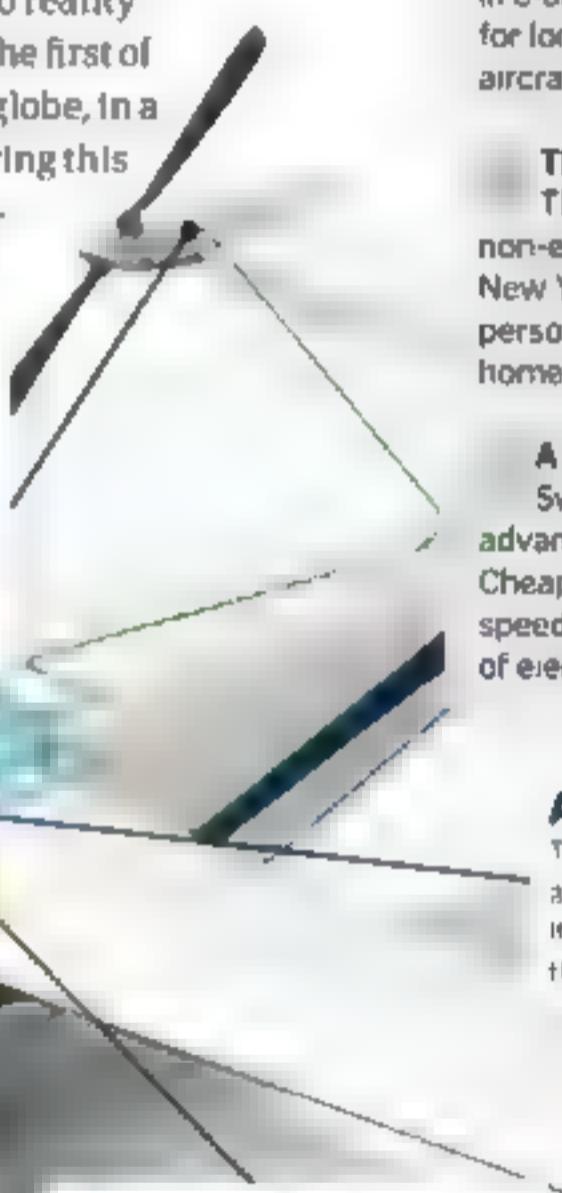
## The damage of flying

The emissions per person on a non-electric flight from London to New York is roughly the same as a person in Europe heating their home for a year.

**A more comfortable journey**  
Switching to electric planes has advantages for passengers. Cheaper tickets, quieter travel and speedier climbs all come as a result of electric engines.

## Air-Intake scoop

The air scoop provides cold air to the plane's components. It can also be used to ventilate the plane cabin.



### Stack of fuel cells

For propulsion, fuel cells are used to convert hydrogen to electrical energy. This produces more energy than a battery alternative.

### Electric motor

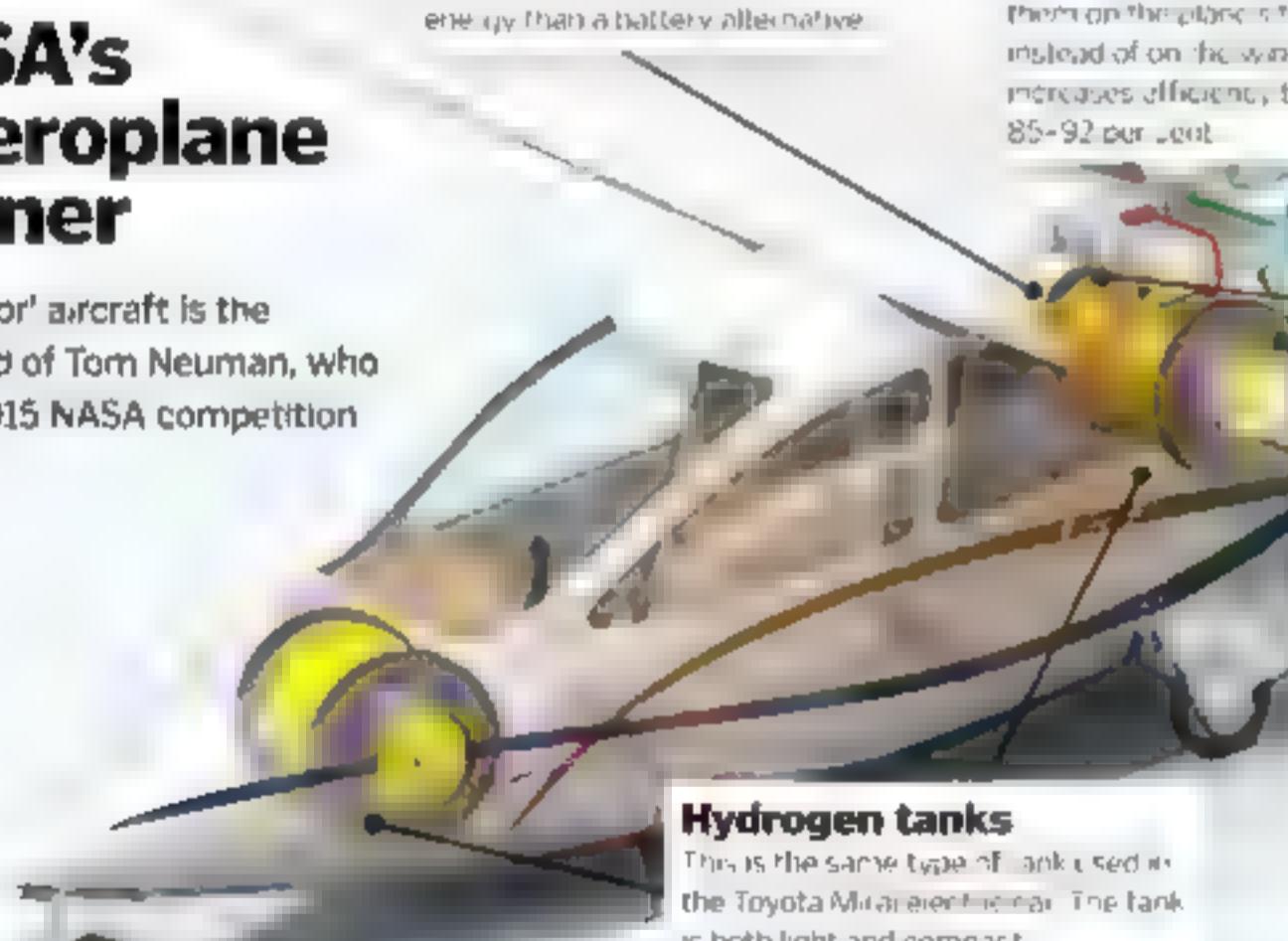
Electric motors make planes more fuel-efficient and quieter. Positioning them on the plane's tail instead of on the wings increases efficiency by 85-92 per cent.

### Air compressor

Compressing the air from outside the plane maintains a constant pressure. The high-pressure oxygen reacts with the hydrogen to release spare electrons.

## NASA's e-aeroplane winner

The 'Vapor' aircraft is the brainchild of Tom Neuman, who won a 2015 NASA competition



# © Mr. Bean

and BRILLIANT\*

The beloved ~~oddball~~ Mr Bean famously drives a 1976 British Leyland Mini 1000 on his adventures. The 'Citron' lime green coloured car is fitted with numerous ~~GENIUS~~ ~~bizarre~~ security features including a bolted latch and padlock on the driver's door and a removable steering wheel.

← Not on this toy model!

\* NB: This product description has been

skillfully corrected by  
Mr Bean  
(of London)



CC82110 Mr Bean's Mini



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# Inside e-bikes

## How electricity is powering a new wave of enthusiasm for cycling

If someone cycles past you up a steep hill looking serene and sweat-free, they're either extremely fit or riding an electric bike. Electric bikes still have pedals and can be ridden like conventional bicycles, but integrated motors add power and propulsion when needed. They range from bikes with small motors that assist when a cyclist is pedalling (known as pedelecs) to models with throttles, which are able to operate like mopeds when the rider engages the motor.

While electric bikes – or e-bikes – have enjoyed a real surge in popularity since the late 1990s, they've been around since the

**Victorian era** Ambitious inventors and engineers first attached motors to bicycles in the 1880s. Electric bikes had the potential to ease traffic and pollution, but heavy, electrically driven wheels and weak batteries made early attempts impractical.

The invention of the lithium-ion battery in 1991 finally made lightweight electric bikes a reality. An e-bike can now cover more than 100 kilometres before it needs charging.

E-bikes don't do all the work for cyclists, but they do make cycling considerably easier and more accessible. From city commutes to countryside adventures, electric bikes reduce

the amount of effort cyclists need to put into their journeys while providing that wind-in-your-hair feeling.

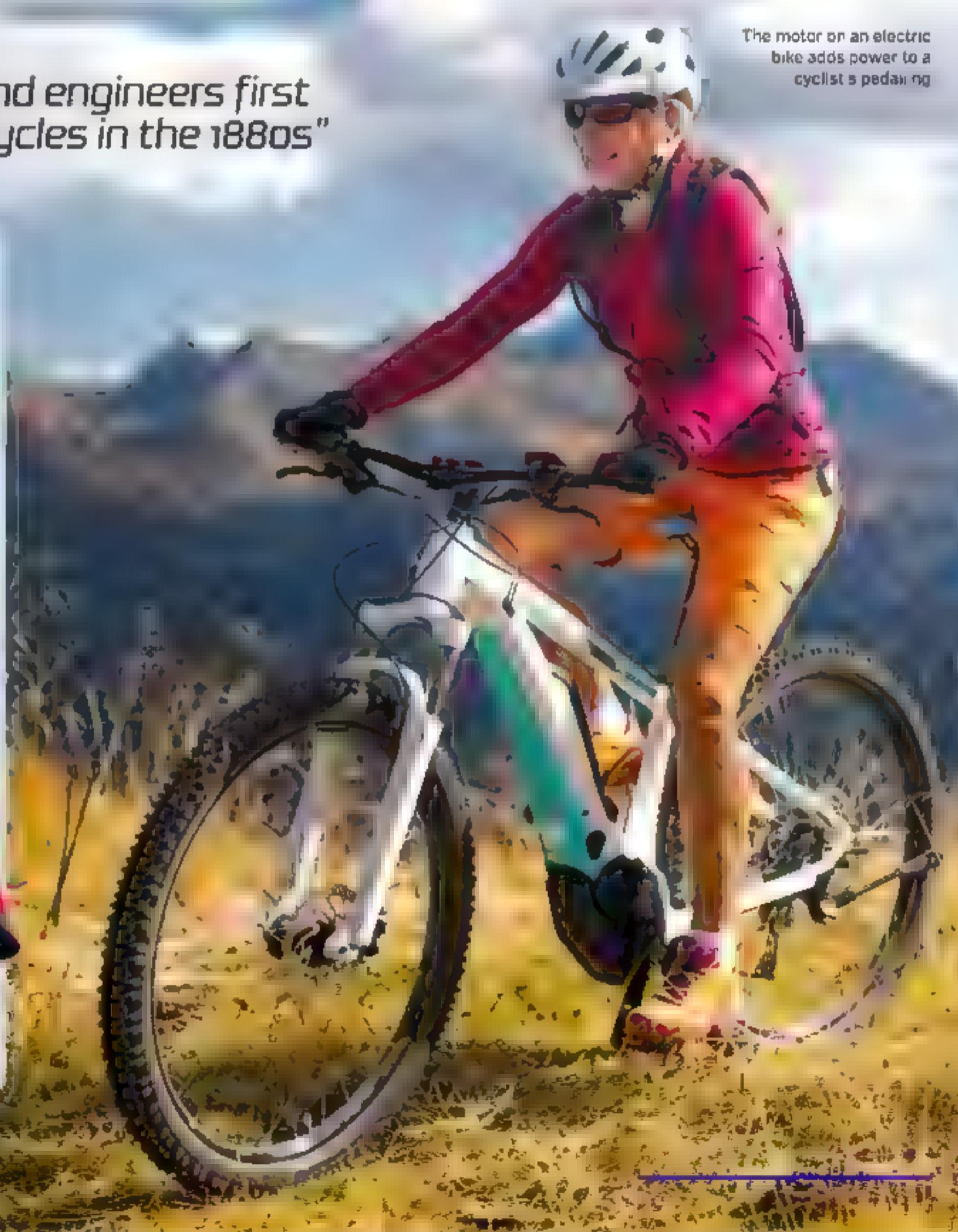
Tens of millions electric bicycles are now ridden every day in China. In the Netherlands adults are buying more electric bikes than non-electric models, and it's predicted that it won't be long before one in three bikes sold across central Europe will be electric. As well as providing financial benefits for the countries manufacturing and distributing the bikes, it's hoped that this boom in sales will improve health as more people choose to cycle.

*"Ambitious inventors and engineers first attached motors to bicycles in the 1880s"*

### Safety first

Electric bikes can make cycling easier and quicker, but they're just as likely to be involved in an incident if not used carefully. Because of their increased weight and speed, it's important to pay careful attention to the road, so you can brake or steer in plenty of time to avoid hazards. Drivers will often base their decisions on the speed of a normal bike, so always stay alert in case a car pulls out in front of you. Cyclists riding electric bikes should also take the usual safety precautions, like using lights and reflective clothing at night and wearing a helmet.

Higher speeds make head protection like this Hedkayse ONE helmet essential while riding an electric bike



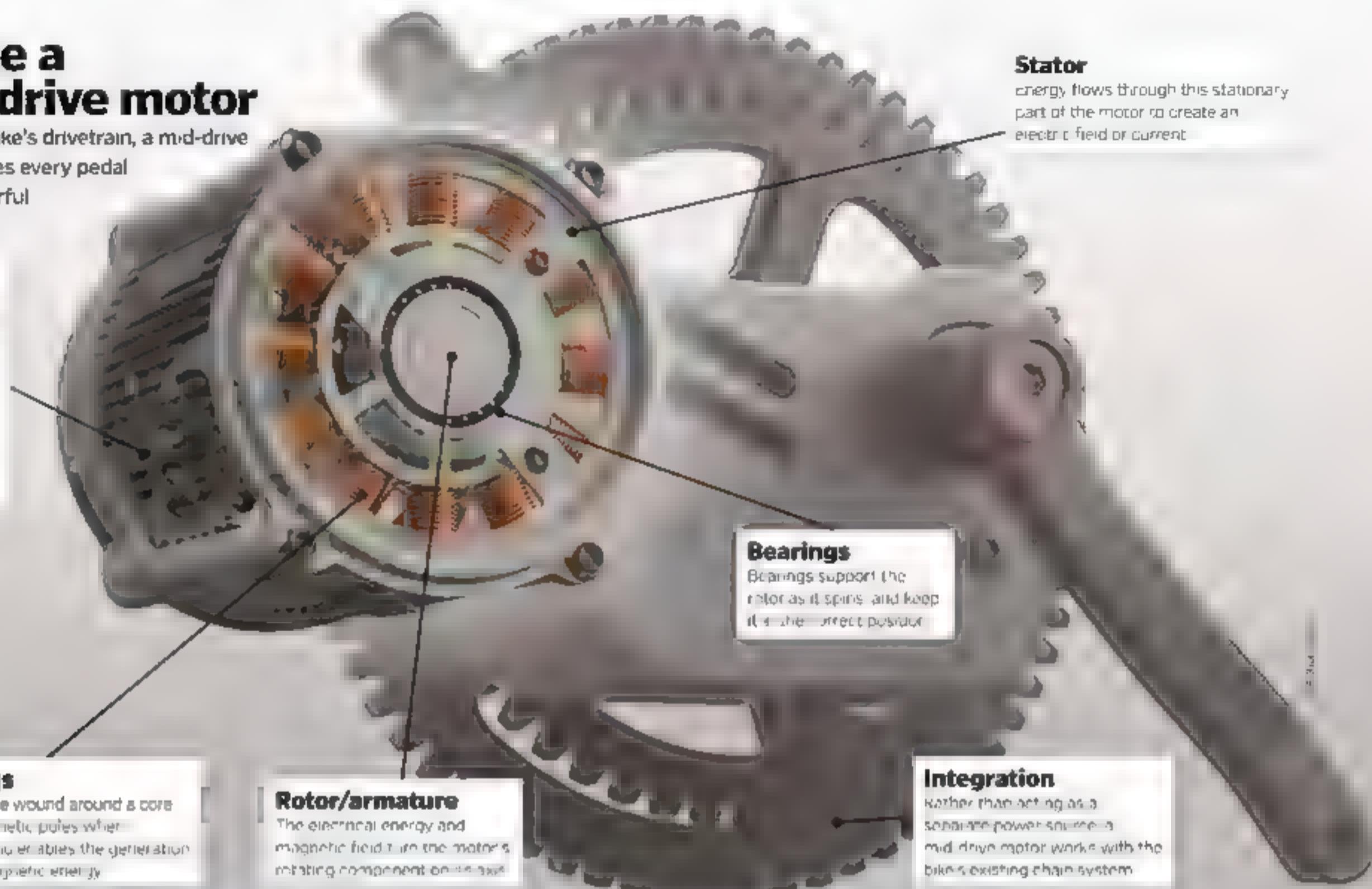
The motor on an electric bike adds power to a cyclist's pedalling

## Inside a mid-drive motor

Using the bike's drivetrain, a mid-drive motor makes every pedal more powerful

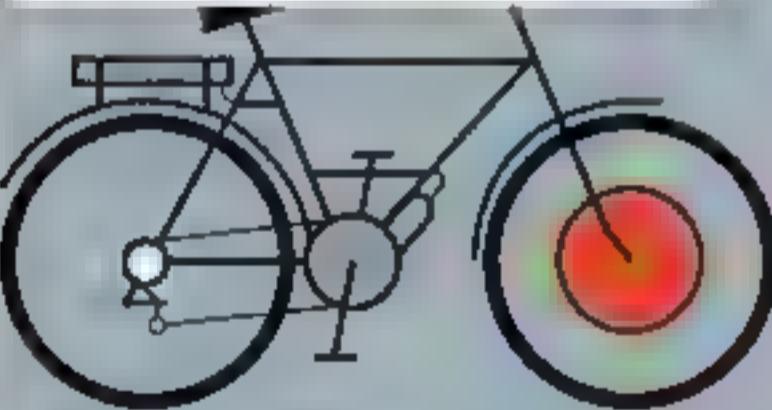
### Shaft

Turned by the movement of the rotor, the shaft delivers mechanical energy and torque to the bike's drivetrain



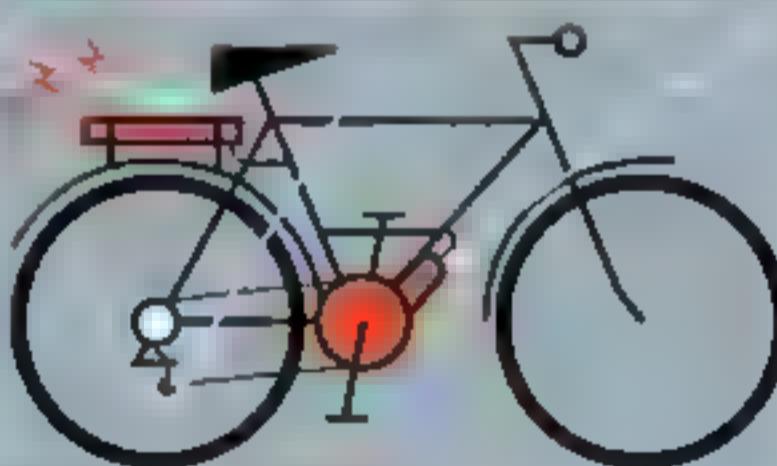
### Battery

Batteries take two to eight hours to charge fully and act as the power source for the bike's motor



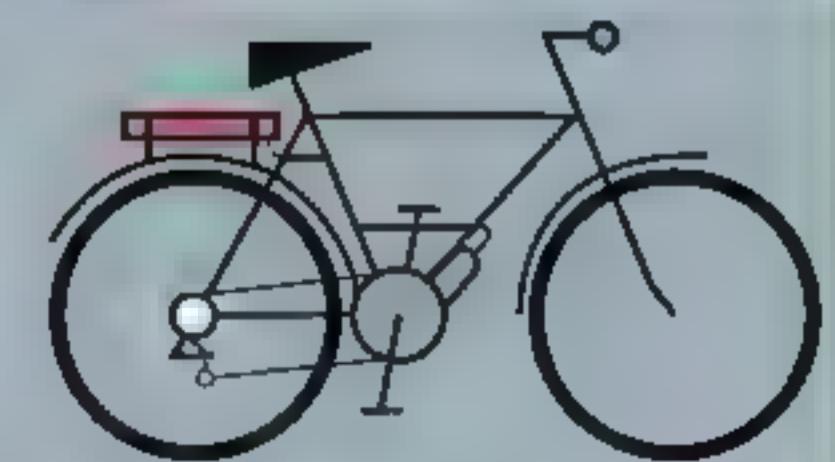
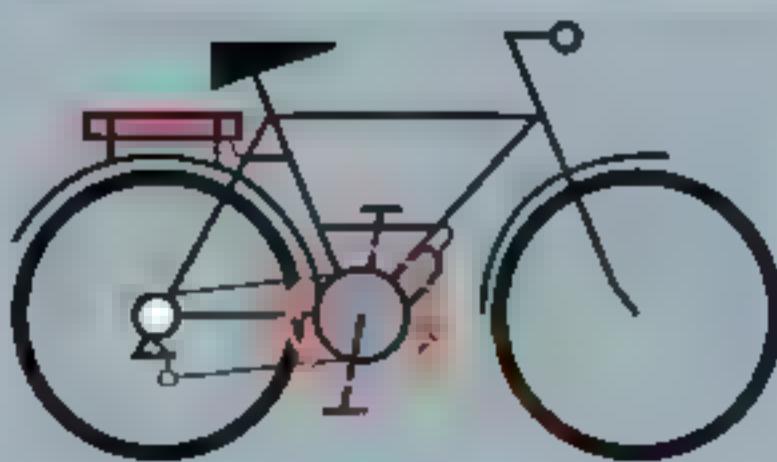
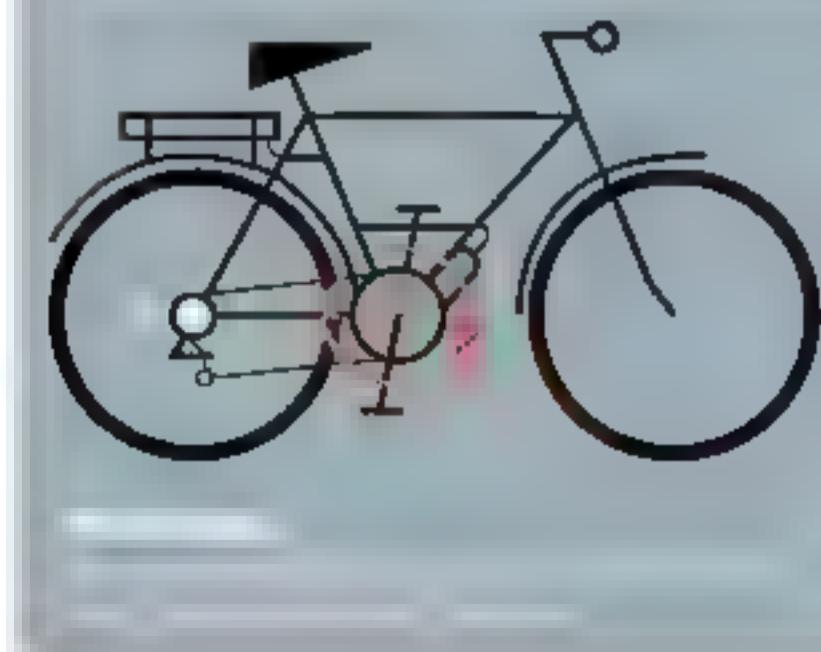
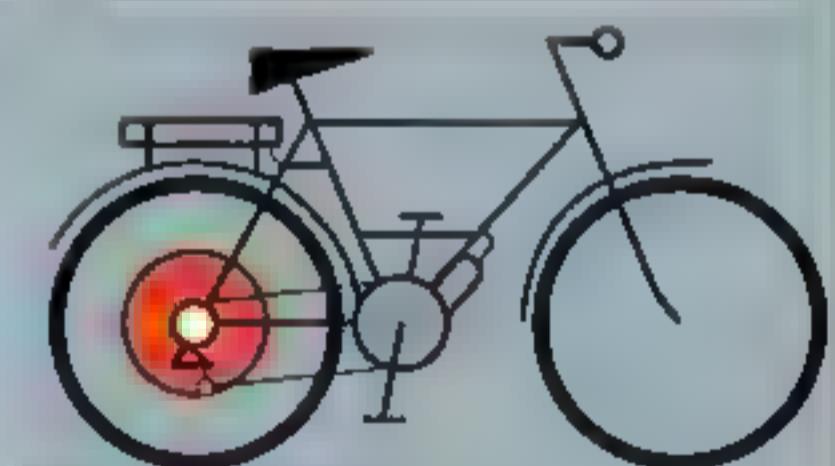
### Drivetrain

The drivetrain is a collection of components that deliver power from the motor to a bike's wheel



### Motor

The motor converts the battery's electrical energy into mechanical energy to propel the bicycle



# How planes use smart radar

The radio waves that keep you safe in the sky and on land

What's the weather going to be this afternoon? Tomorrow? Or even next week? Thanks to the weather forecast, we are able to plan ahead when it comes to the weather. Long gone are the days when you could only rely on a glance out of the window in search of a dry day.

Weather forecasts often show predictions for large areas of the country, but smart weather radars make it possible to receive precise climate conditions for the exact location where they are placed. You can even buy weather stations designed for your home that send automatic message notifications when extreme conditions are expected.

Hyperlocal results provide higher accuracy in a weather radar's feedback. This becomes useful for closely following updates, especially when they could cause danger. Examples of when this

technology is required includes on transport that's affected by weather, as well as in agriculture, to show flood warnings.

But how is the information collected? Radar stands for radio detection and ranging, which is used by weather stations and aeroplanes to send radio waves out into the sky. The waves bounce off the nearest object - like a cloud - they come into contact with and return to be analysed.

Data from these radars can determine details about precipitation in an area, such as its location, how much precipitation is in the air, its movement and the likelihood of future snow, hail or rainfall.

Additionally, the radar system can predict the possible effects of incoming storms. While we often seek weather forecasts for convenience, this information holds the more important purpose of ensuring safety.

## The speediest surveillance

Phased array radars (PARs) can be used to detect weather conditions electronically, using an array of antennae. The beams from these radars can be steered quickly for fast and accurate weather forecasts.

High-speed tracking means that these radars not only save time but occasionally lives too. They have been used to warn people about severe weather in advance, such as in the US where they have been able to prepare for incoming tornadoes.

PARs contain panels that face in every direction. Unlike many weather stations, which need to rotate to cover the surrounding areas, PARs remain stationary, scanning the entire sky in under 60 seconds. Tracking both air and ground level at the same time, these qualities also provide a perfect use for navigating warships in many navies, as well as controlling missiles.

This phased array radar in Taiwan detects typhoons. Its dome shape allows radio waves to be sent in every direction.



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# WHAT IS PERMAFROST?

Words: Amy Gladwell

most 25 million square kilometres of Earth's ground is frozen in tundra. Permafrost covers nearly as much of the planet as Russia does. Soil, silt or clay must stay at zero degrees Celsius or lower for two years to qualify as permafrost, and it's over one kilometre thick in parts of Siberia. Some areas of permafrost are so laden with ice that it's twice the weight of the soil around it. In Alaska

subterranean blocks of ice much 15 metres deep can span 300 kilometres.

These vast frozen areas are remnants of the last ice age. They formed over thousands of years and have survived until the present day. Each summer the top layer of the frozen soil could thaw enough for plants to grow. As time went on, a lot of organic matter found its way into the soil. Eventually vegetation would grow



010 - 0117.02 Some permafrost bacteria live 400 metres deep at temperatures of -27 degrees Celsius



Previously frozen ground  
implodes when it isn't held  
together by ice any more



## How to hunt a mammoth

which end up in China. Carved ivory ornaments are a popular souvenir, but mammoth ivory is illegal in China. Mammoth ivory is considered an older form of ivory on the demand for it is six times that of African ivory. A 65-kilogram tusk fetches \$10,000.

As not only is the scientific community

concerned, so are the hunters.

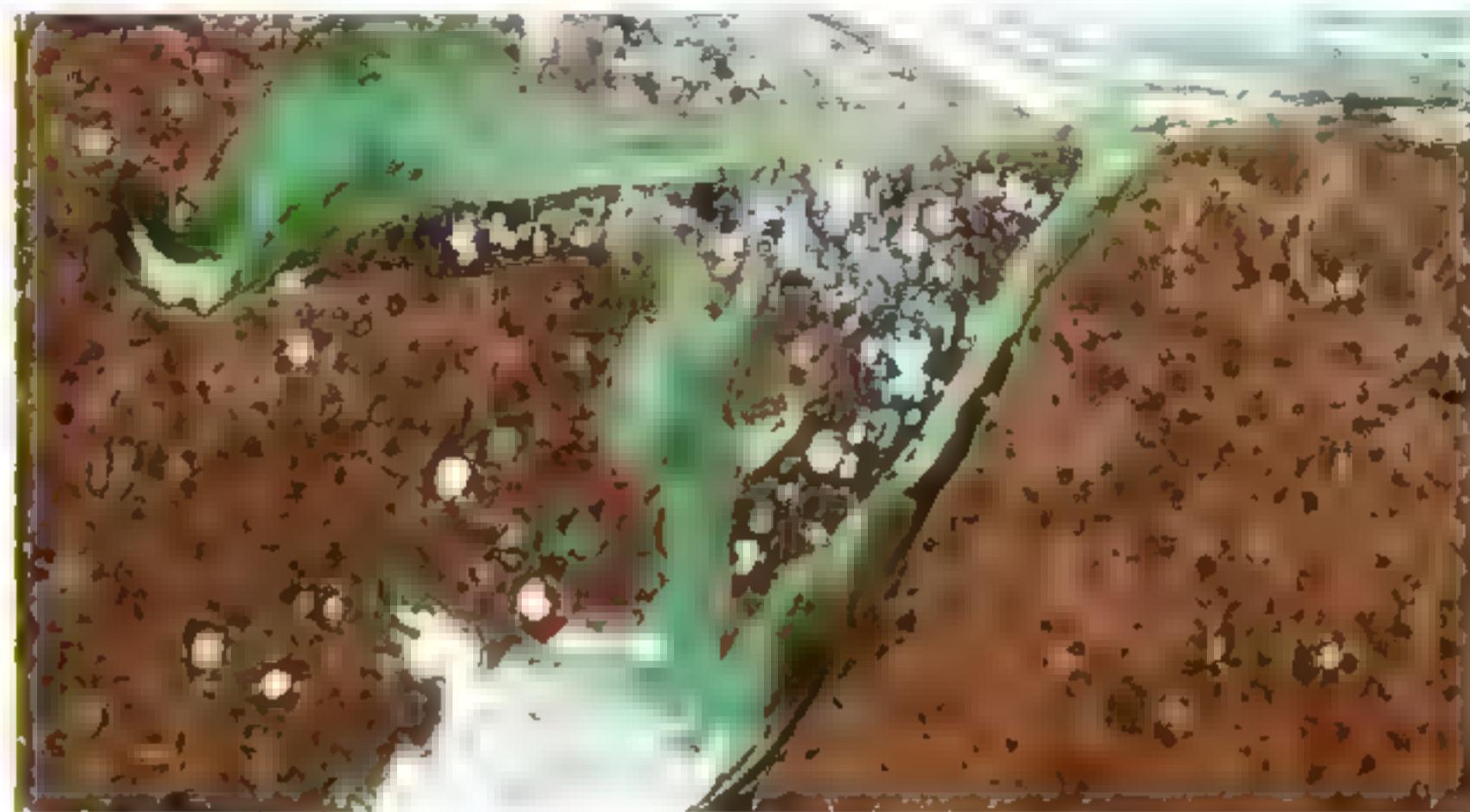
Mammoth hunters blast the ice with

### Species

The number of tusk still enough to hunt seems to have diminished significantly, and hunters are struggling to find valuable prehistoric tusks now that they are in low supply.



### Permafrost



A satellite image of the north Siberia coast, showing thermokarst lakes, which are pockets of permafrost meltwater

remains were buried in the permafrost, where they couldn't decay. Intact remains of extinct megafauna are found in permafrost to this day in near-pristine condition.

All of this tissue would rot if global temperatures got high enough to melt the permafrost that's keeping it preserved. The bacteria that feed on decomposing material release greenhouse gases. If the planet gets hot enough, melting permafrost could accelerate climate change.

Permafrost prevents the ground from absorbing water, creating wetlands and lakes that normal rainfall couldn't sustain. People and wildlife rely on these environments to survive, and the loss of permafrost would have an

enormous impact. If subterranean ice were to melt, the land would change drastically. Some areas would dry out, while others would get wetter. The chemical makeup of the water would change and the ground would become irregular. The new landscape could alter the course of rivers, affecting fish and wildlife.

Unfortunately permafrost is beginning to melt thanks to our changing climate. While the loca-

*"Polar release of methane alone could double in the next 100 years"*



## How melting ice releases carbon

The planet's natural carbon cycle is under threat from the warming polar regions

### Into the air

Emissions enter the atmosphere and re-enter the carbon cycle. Excess greenhouse gases cause further global heating.

### Slow but sure

Permafrost thaw happens at a gentle pace but is an irreversible change. Projections of global warming suggest that melting will be slow but prolonged.

### Bacterial growth

Microbes digest organic material from dead plants, and expel carbon dioxide and methane as a result.

Vegetation

Soil

Permafrost

Rock

### Endless loop

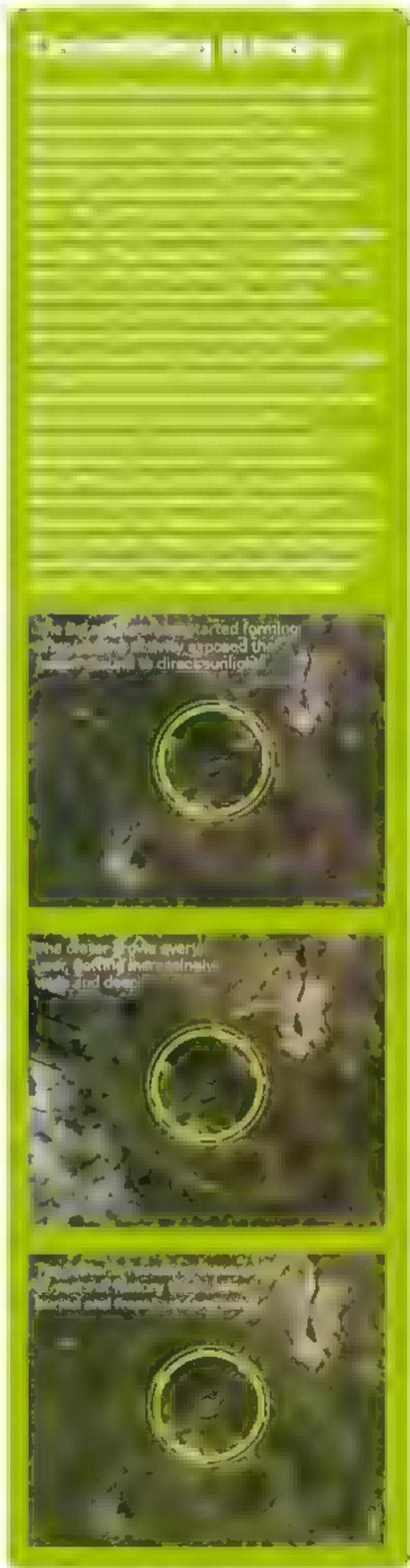
Melting creates a feedback system, where carbon travels from the soil to the atmosphere, and then back through processes like photosynthesis. Excess greenhouse gases don't return to the cycle and increase global temperatures.

### Warming planet

Carbon dioxide, methane, nitrous oxide and water vapour trap heat in the atmosphere. Polar release of methane alone could double in the next 100 years.

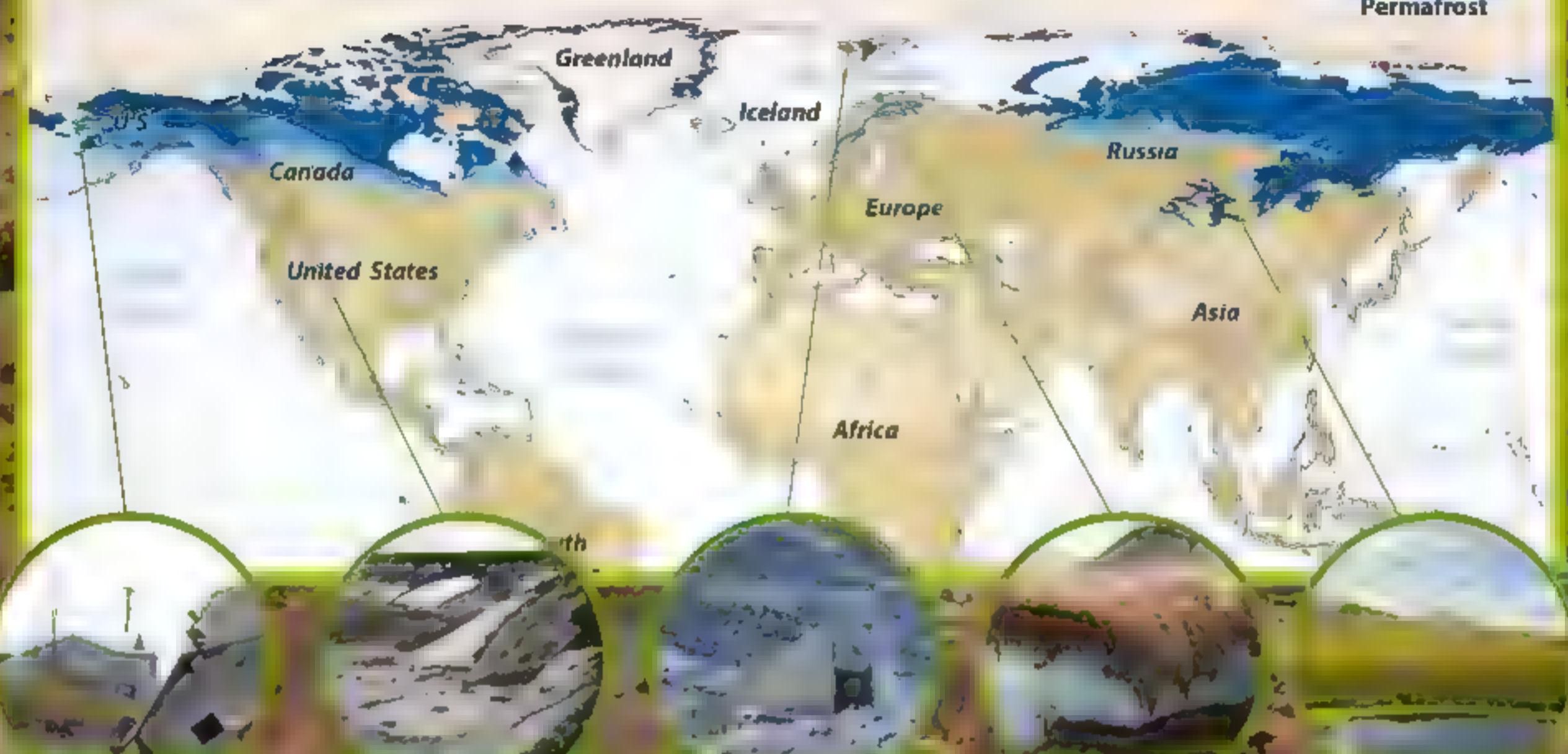
### Impending disaster

We have a carbon budget to monitor how much we have to reduce emissions by. We've already released two-thirds of this allocation, and permafrost melt could use up 13 per cent of the remainder.

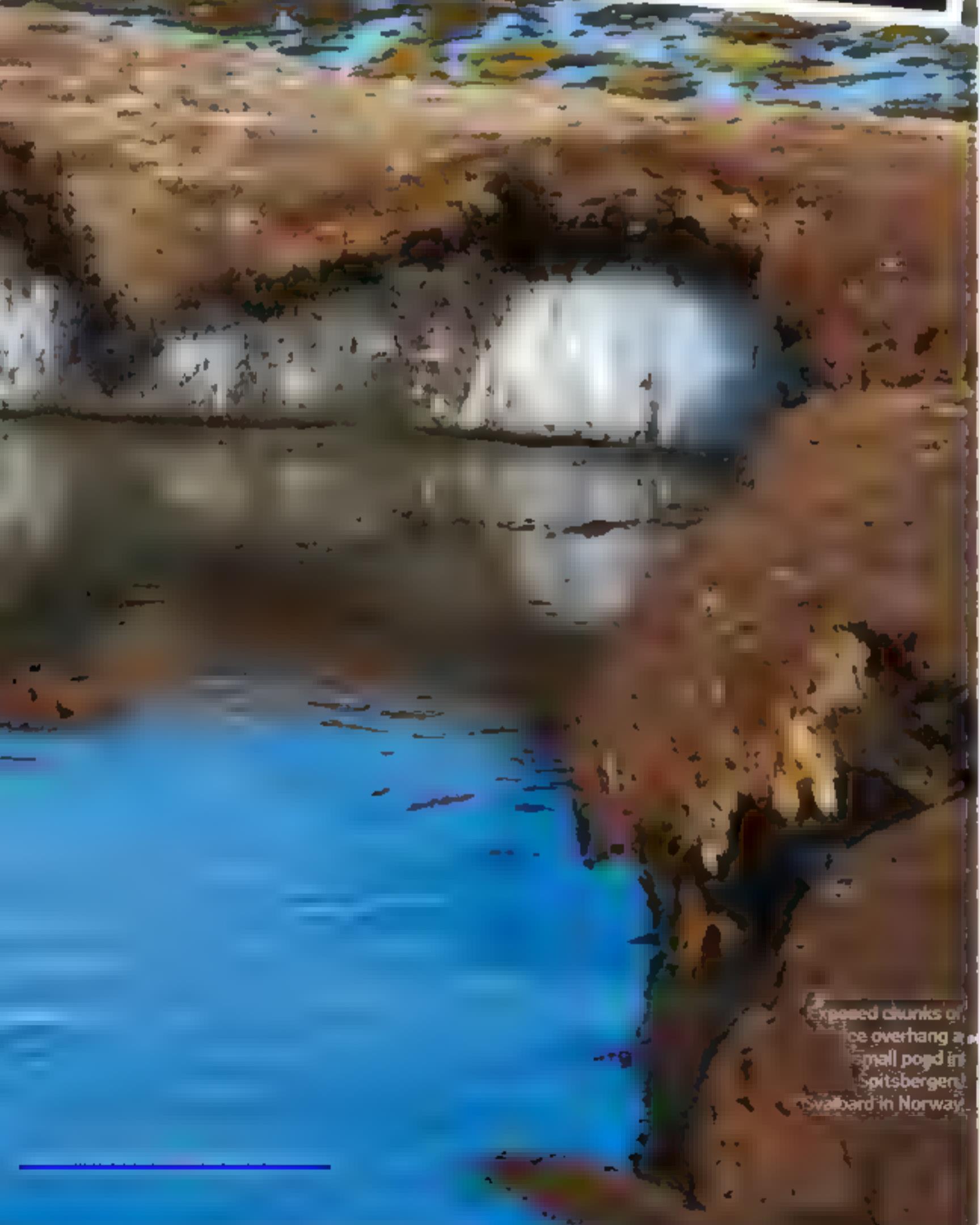


## Permafrost hotspots

Arctic



*We have little information about their physiology and metabolic demands. We can't be sure what will happen if they begin to feast on all the carbon-filled organic matter frozen beneath them.*



area will be threatened, there may also be consequences for the entire planet. The Arctic takes up more carbon than it makes, so we call it a carbon sink. The plants that grow throughout the continent suck up carbon from the air in photosynthesis. If the Arctic gets hot enough to thaw permafrost, it could become a source of greenhouse gases. This could be the point of no return for the planet. Extra hydrocarbon release would lead to increased warming, which in turn would cause more hydrocarbon expulsion from melting ice. As much as 1.4 trillion tons of these gases could be locked up in permafrost.

Half of the organic material buried in the Earth's soil is frozen. A temperature increase of just a few degrees could melt permafrost and allow the plant and animal remains to break down. Earth has warmed up by 0.8 degrees Celsius since 1880 - and estimates suggest that a temperature increase of just one degree Celsius could jeopardise more than a quarter of the planet's permafrost.

## Frozen layers examined

The surface of permafrost is called the active layer. This is where the soil freezes and thaws annually. The ground just below the active layer is called the permafrost table. One gram of soil might hold more than 1 billion micro-organisms. All of these microscopic organisms cannot be frozen in the conditions, but we have little information about their physiology and their tolerance to cold. We can't be sure what will happen if they begin to decompose carbon-rich organic matter from permafrost.

Ice wedges are described as vertical columns of frozen water content around 150 per cent. These are the result of large water reservoirs under the ground.

Permafrost and surface flow. Temperature rise, less and less of the permafrost survives to the next winter. The active layer is getting thicker as the ice beneath retreats, and the coldest areas of permafrost are losing the coldest.

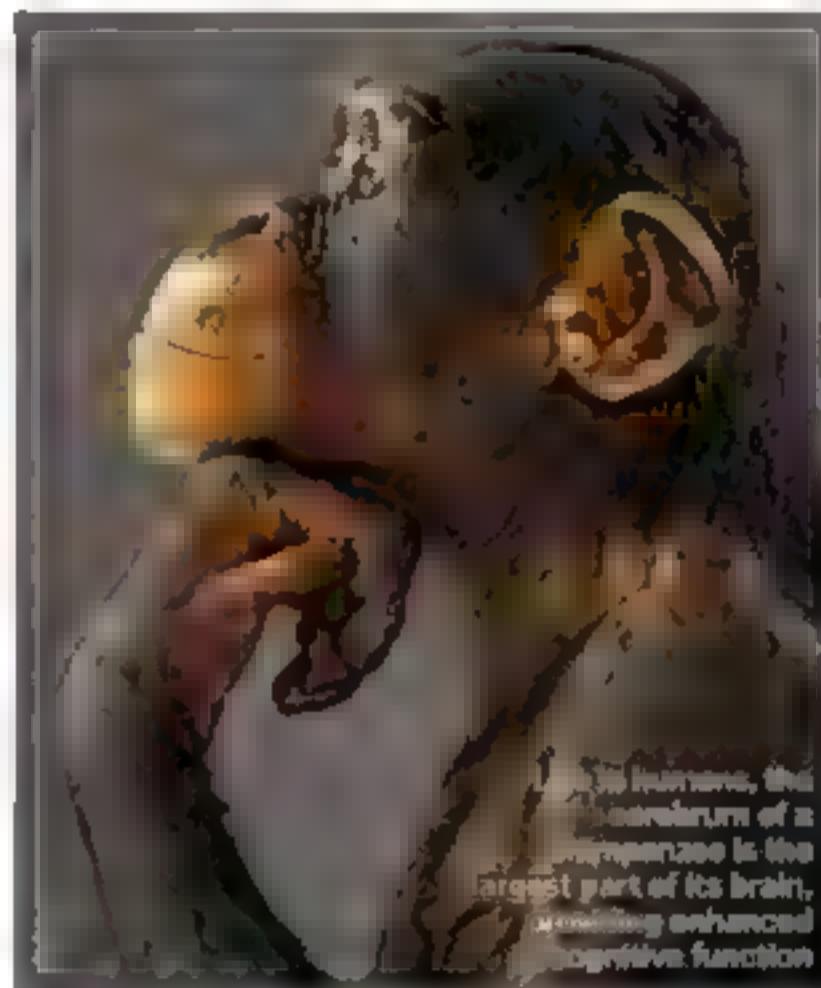


# Animal brain anatomy

When it comes to what's between our ears, some animals are surprisingly similar to us

**T**he animal kingdom is filled with brainy beasts, each with their own intelligence adapted to their way of life. Each of the five groups of animal to have a spine, known as vertebrates, has a brain. As a condensed collection of electrically stimulated nerve cells, this organ is the control centre for an animal's entire body, operating its senses, instincts and behaviour. However, when it comes to their brains, it's not a case of one size fits all. Fish, amphibians, reptiles, mammals and birds have evolved brains with a similar function, but they vary in form.

There are four distinct areas of the vertebrate brain: the cerebrum, optic lobe or tectum, cerebellum and medulla oblongata. The brains of different vertebrate species each have different regions that are larger and more complex than in other animal groups. For



example, the optic lobe in bony fish is proportionally larger than any other animal group. Evolved to spend their lives in water, their survival depends on the ability to be aware of their surroundings. Therefore, having more brainpower to process visual information is vital. However, in mammals this region of the brain is minute, and its function has been integrated into the cerebrum.

As the most advanced in terms of cognitive ability, mammals possess a large cerebrum – the site of more complex neural and sensory functions. Some species have evolved the ability to become self-aware, such as apes. This is due to the vast amount of neurons packed into their enlarged cerebrum. The folds in these are important as they increase the surface area, allowing a greater number of neurons to process more information.

## Inside the animal mind

### Cerebrum

The cerebrum is the information house. It stores, processes and translates neurological information involved in voluntary movement, sensory information, communication and memory.

### Optic lobe

Within the midbrain, these lobes play a vital role in visual information processing.

### Cerebellum

This region of the brain assists with the animal's motor skills, such as walking and coordination.

### Medulla oblongata

As the point where the brain stem merges with the spine cord, the medulla oblongata regulates heart rate, respiration and also blood pressure.

### Olfactory bulb

This is the site of smell transduction – a vital ability in the animal kingdom for detecting food and being alerted to danger.



Special offer for readers in **North America**

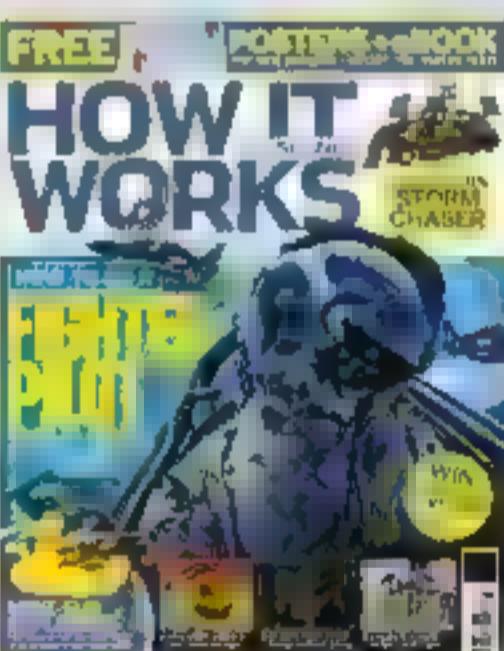
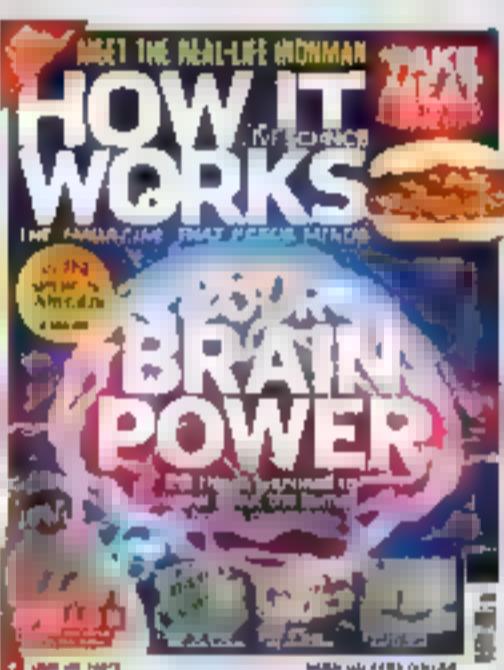


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# HUMAN HABITATION



To survive on Mars, we'll need something to live in. Could these homes be the answer?

Words by Jonathan O'Callaghan

For decades, sending humans to Mars has been one of the main goals of our space exploration endeavours. Countries like the US and China, and companies such as SpaceX have all expressed a desire to colonise the Red Planet. But to do so, we will also need a way for humans to survive – and thrive – on the surface of this hostile world. And efforts have been long underway to do just that, by designing habitats that humans may live in.

Building a habitat on Mars poses particular challenges that are not faced anywhere on Earth. First there is the lack of pressure – about one per cent of Earth's at sea level – which means habitats must be pressurised. There are also vast temperature swings, from 20 degrees Celsius to as low as -153 degrees Celsius as day turns to night and the Sun's heat escapes through the thin atmosphere. A lack of obvious resources like building materials and water also poses a significant challenge, as does coping with less sunlight – about 44 per cent less than we experience here on Earth.



Entertainment will be important on Mars to stop the astronauts from getting bored

The walls of the MARSHA habitat will be layered to block radiation and provide insulation



*“Building a habitat on Mars poses particular challenges”*

To overcome some of these challenges, NASA has been running the 3D-Printed Habitat Challenge since 2015, to see if anyone can come up with viable solutions to these problems. 3D-printing is deemed to be one of the best ways to build habitats on Mars, reducing the amount of mass that will need to be carried to the surface – especially if we can use Martian resources to print them.

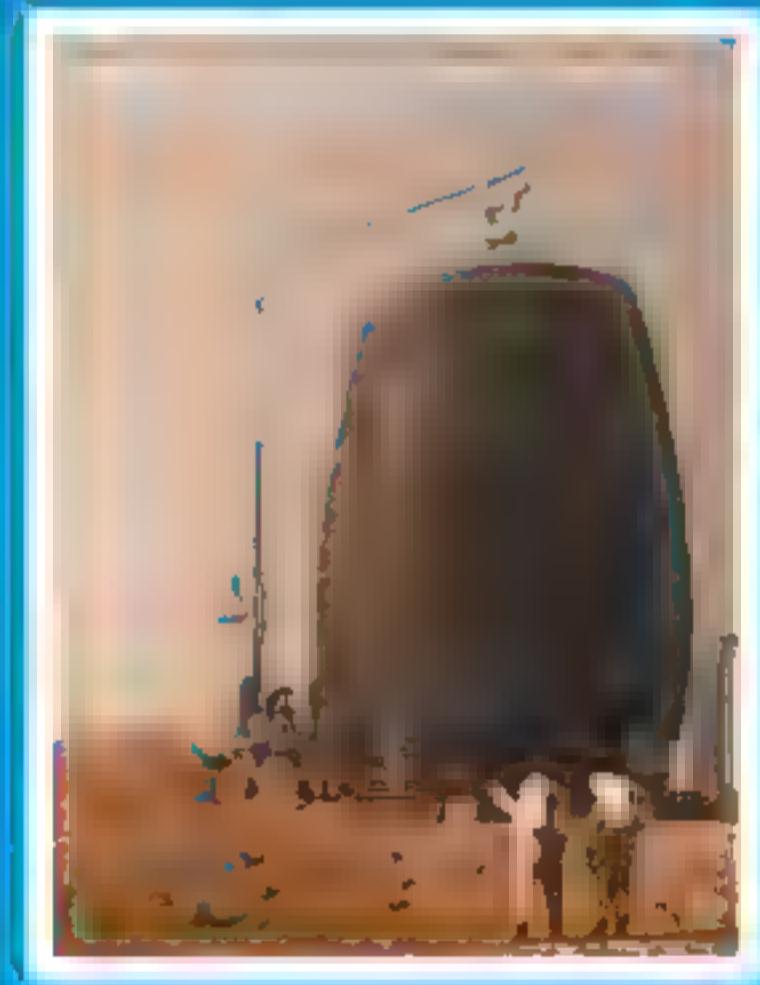
In May 2019, two teams were awarded a combined \$700,000 (around £580,000) to further develop the ideas they had suggested – one from New York-based AI SpaceFactory, called MARSHA, and another, Den@Mars, developed by Pennsylvania State University. Both make use of a curved structure in order to reduce the pressures on the habitat while on Mars. But while Den@Mars is a more traditional dome, MARSHA is a cylindrical shape – one of the factors that earned it the top prize from NASA of \$500,000 (around £415,000), after successfully printing a one-third scale model of the design in 30 hours almost completely autonomously.

NASA hopes that these designs, or some variant of them, may form the basis of eventual Mars habitats when humans land there at some point in the 2030s or later. Many challenges remain, however, not least working out how to actually land the equipment on Mars that could print these structures, and ultimately sending humans there too. But if some of these challenges can be overcome in the near-term, it raises the prospect of eventual missions in the future.

## Mars materials

To build a habitat on Mars, MARSHA will use materials directly from the surface of Mars to reduce the amount of resources that need to be carried from Earth. The habitat will be built using basalt fibre extracted from the Martian rocks combined with a renewable plastic called polylactic acid (PLA) that can be processed from plants grown on Mars.

The resulting material has a similar strength to carbon fibre yet is much easier to make, while the plastic is a great shield against cosmic radiation. Using PLA also ensures the material is recyclable, and it will not expand and contract too much as temperatures on Mars change. The idea is that a machine on Mars, like a large crane, will be able to use this material to autonomously produce the habitats for astronauts to live inside, once the resources have been produced on the surface.





## Martian houses

Here are some of the other designs in NASA's Mars habitat competition that were considered

### Team Kahn-Yates

This team from Jackson, Mississippi, designed a Martian habitat with a mottled design, that can cope with dust storms and the harsh climate on Mars.



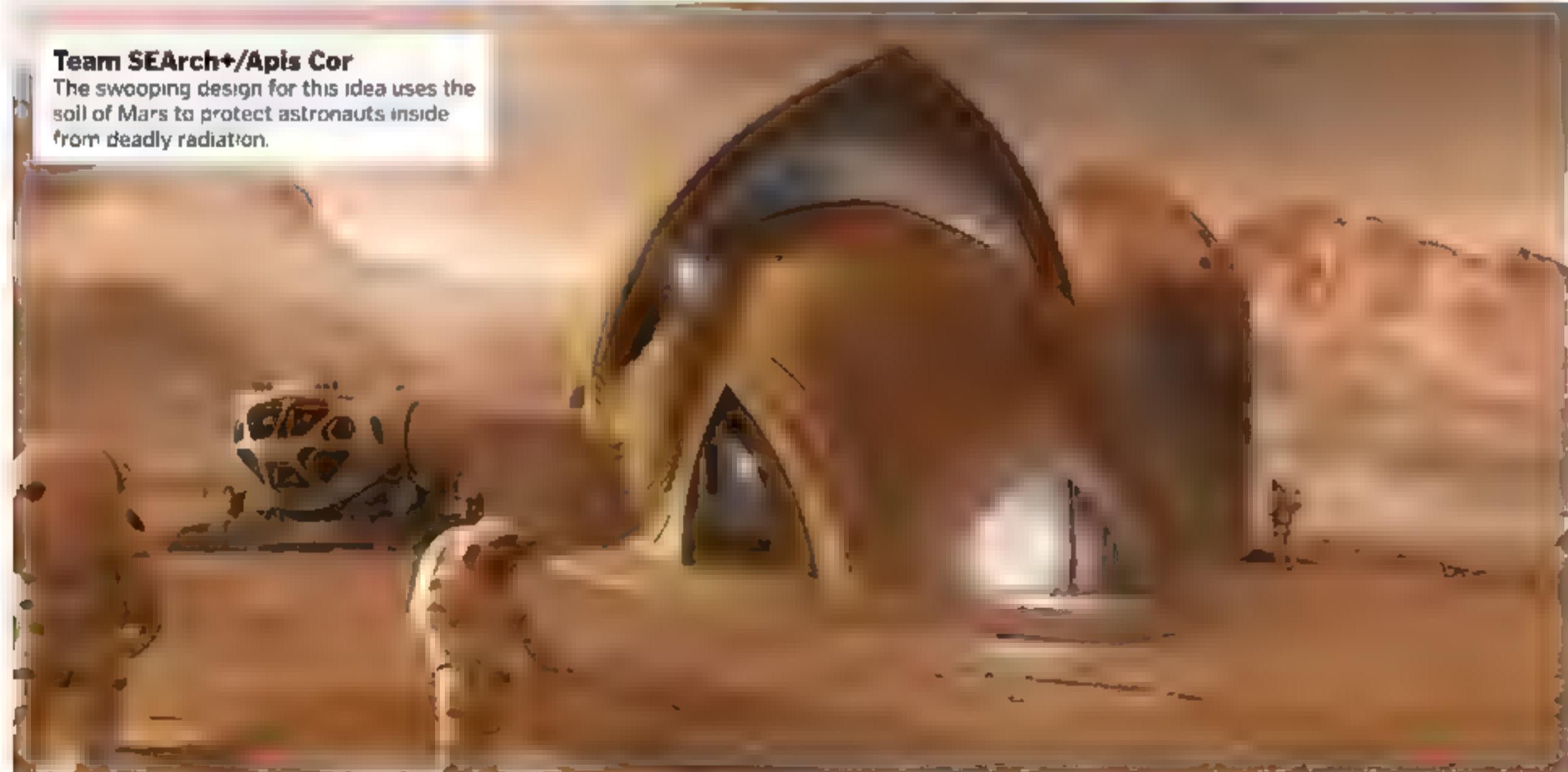
### DendroMars

This idea from Pennsylvania State University planned to use digital scanning and a nozzle to squirt out a paste-like substance to produce a dome shaped structure.



### Team Search+Apis Cor

The swooping design for this idea uses the soil of Mars to protect astronauts inside from deadly radiation.



## 5 FACTS ABOUT NTH

### 1 Lower gravity

Mars has just 38 per cent of Earth's gravity, so astronauts on Mars will need to exercise regularly to overcome any loss in bone density and muscle mass.

### 2 Space radiation

The thinner atmosphere of Mars means that astronauts will be exposed to much more solar and cosmic radiation, and must remain protected on the surface.

### 3 Launch windows

Owing to the orbits of Earth and Mars, missions between the two can only be launched every 26 months, and it will take about eight months to make the journey.

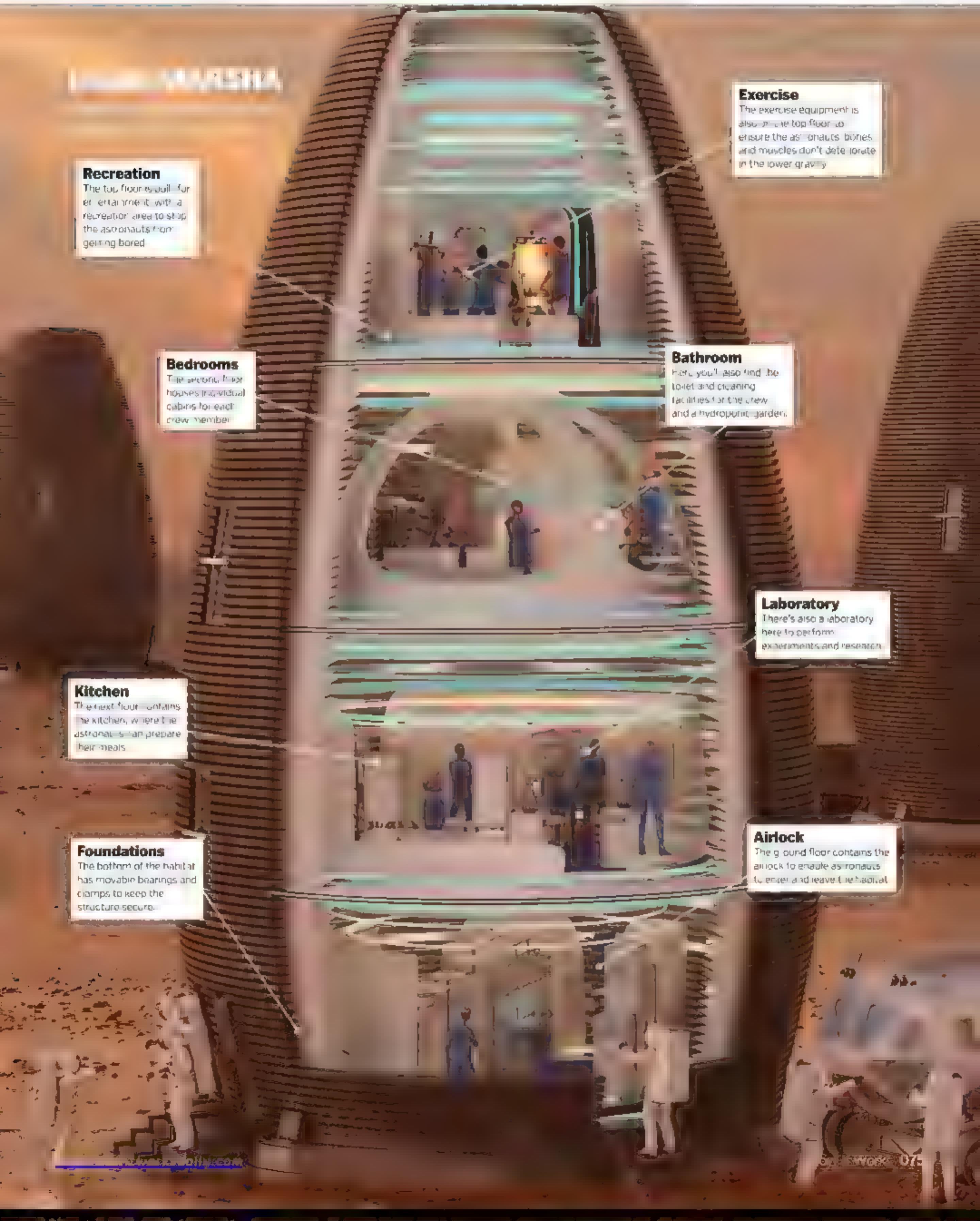
### 4 Martian water

Water cannot exist as a liquid on Mars because of the low pressure. But it's thought to be frozen under the surface as ice, which could be used by astronauts.

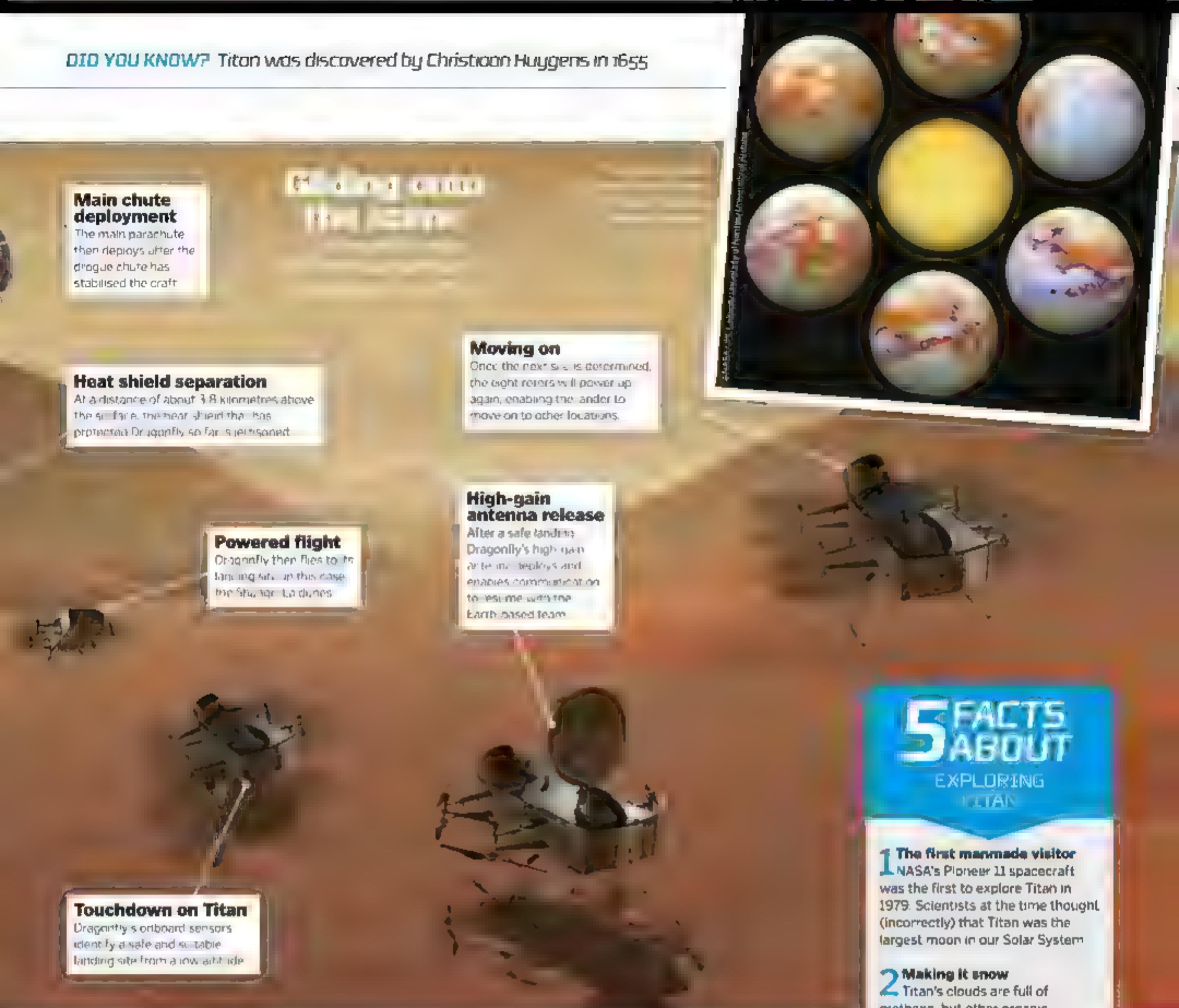
### 5 Life on Mars?

It's possible that Mars could play host to some form of microbial life. And perhaps it will take astronauts going there for us to find out for sure.

**DID YOU KNOW?** Elon Musk's SpaceX company wants to have 1 million people living on Mars by the end of this century







### Main chute deployment

The main parachute then deploys after the drogue chute has stabilised the craft

### Heat shield separation

At a distance of about 3.8 kilometres above the surface, the heat shield that has protected Dragonfly so far is jettisoned

### Powered flight

Dragonfly then flies to its landing site, in this case the Shangri-La dunes

### Moving on

Once the next site is determined, the eight rotors will power up again, enabling thelander to move on to other locations

### High-gain antenna release

After a safe landing, Dragonfly's high-gain antenna deploys and enables communication to resume with the Earth-based team

### Touchdown on Titan

Dragonfly's onboard sensors identify a safe and suitable landing site from a low altitude

### • June 2019

NASA confirms the Dragonfly mission as the white-enclosed team's next host of another exhilarating expedition

### • 2026

The Dragonfly space probe begins its voyage – a 10-year journey in the outer Solar System

### 2034

The space probe faces its longest and most challenging test: landing safely on the moon

### • 2036/2037

The planned mission for Dragonfly ends after a duration of 27 years, exploring multiple sites around the ocean world

## How will the drone fly?

Since the 1990s, aerial mobility has been in increasing demand on Earth, which has led to the evolution of drones. Now this mission will use a drone for the exploration of a moon over 1 billion kilometres away. Titan has low gravity and an atmosphere four times as dense as Earth's. This makes it easier for Dragonfly to fly using its eight rotors, travelling around 175 kilometres across the surface over a three-year-long mission. It's further than any Mars rover has travelled. Due to Titan's thick atmosphere and distance from the Sun, it's not possible to use solar power, so the drone will use a Multi-Mission Radioisotope Thermoelectric Generator (MMRTG), like the one on the Curiosity rover.



## 5 FACTS ABOUT EXPLORING TITAN

**1 The first manmade visitor**  
NASA's Pioneer 11 spacecraft was the first to explore Titan in 1979. Scientists at the time thought (incorrectly) that Titan was the largest moon in our Solar System

**2 Making it snow**  
Titan's clouds are full of methane, but other organic compounds form in the atmosphere and fall like light snow onto the moon's surface

**3 Investigating the surface**  
Dragonfly will have different spectrometers onboard that will determine the surface composition at dozens of locations on Titan, which will characterise its prebiotic chemistry

**4 Familiar sights**  
Some areas on Titan are analogous to areas on Earth. For example, some of Titan's dune fields are similar to dunes in the Namib Desert.

**5 Treading lightly**  
Titan has a diameter of 5,150 kilometres, just larger than Mercury, and has a surface gravity that's just one-seventh of Earth's.

# MEGA CREEPY CRAWLIES

Meet the giant prehistoric creatures that once roamed the Earth hundreds of millions of years ago

Words by Scott Dutfield

**3**50 million years ago the Earth was covered in dense forest that was a perfect habitat for giant creepy-crawlies. Arthropods are a collection of invertebrates with jointed limbs – creatures such as spiders, crabs and insects that sport an exoskeleton and a segmented body. First appearing around 545 million years ago, during their evolution this animal group has diversified to make up around 80 per cent of all known species on Earth. However, the small arthropods of today are a fraction of the size of their ancestors, which

once grew up to several metres long. The era of the giant arthropods began during an explosion of life in the Cambrian Period, when these giants lived in the world's oceans.

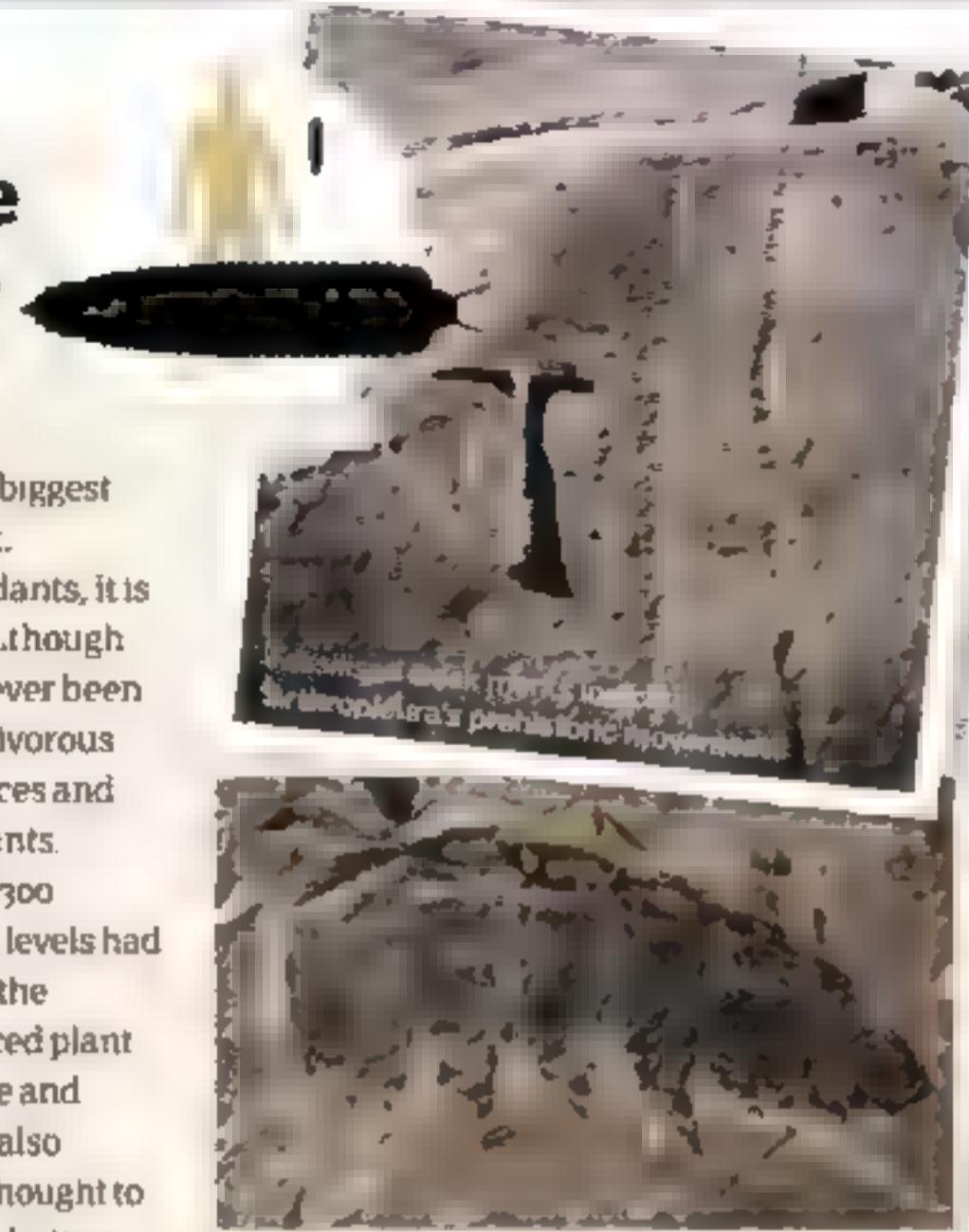
Over millions of years the surface of the Earth became more lush with vegetation. An increase in plant life brought a richer oxygen atmosphere, a key ingredient for supersizing arthropods. By the time of the Carboniferous Period (from about 360 to 299 million years ago), oxygen made up 35 per cent of the atmosphere, compared to the 21 per cent we currently have in the atmosphere today.

## Mega millipede

Scurrying through the dense foliage of a Carboniferous forest 340 million years ago was once a colossal millipede. At around 2.6 metres in length, *Arthroleura* is perhaps the biggest arthropod to crawl across the planet.

Much like its modern-day descendants, it is believed to have been a herbivore. Although the mouth of an *Arthroleura* has never been found to assess the presence of carnivorous teeth or mandibles, its fossilised faeces and digestive tract revealed spores of plants.

By the start of the Permian Period (300 million years ago) the world's oxygen levels had begun to decline. In a domino effect, the reduction of oxygen resulted in reduced plant growth. Not only vital as a food source and oxygen provider, the lush vegetation also provided moisture. *Arthroleura* is thought to have been starved of atmospheric hydration and dried into extinction 290 million years ago.



Completely encased by its exoskeleton, this two-metre-long millipede was an armoured giant

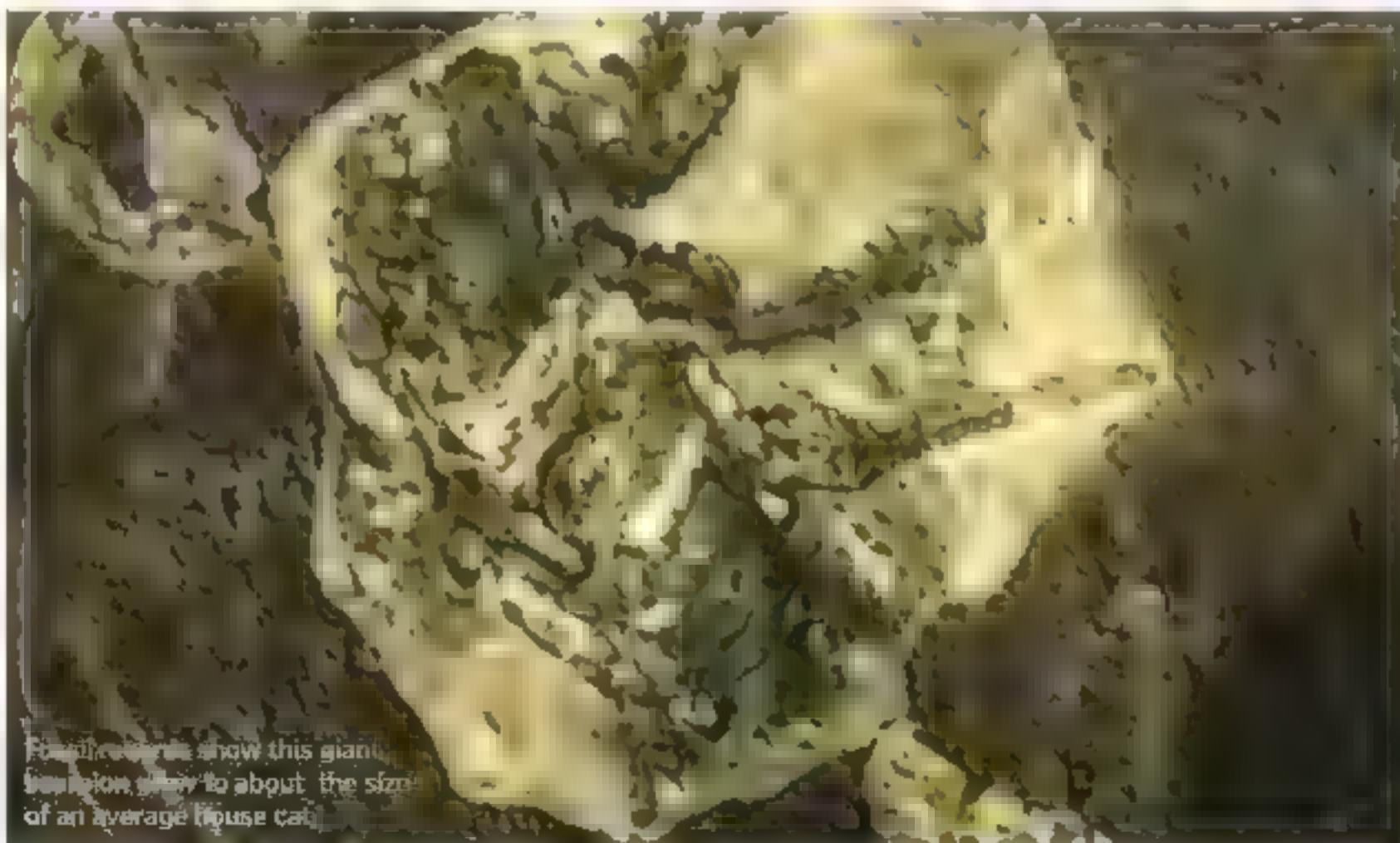
## Supersized scorpion

As the true scorpion king *Pulmonoscorpius kirktonensis* dominated the arachnid scene, with an exoskeleton spanning 70 centimetres from pincer tip to tail sting.

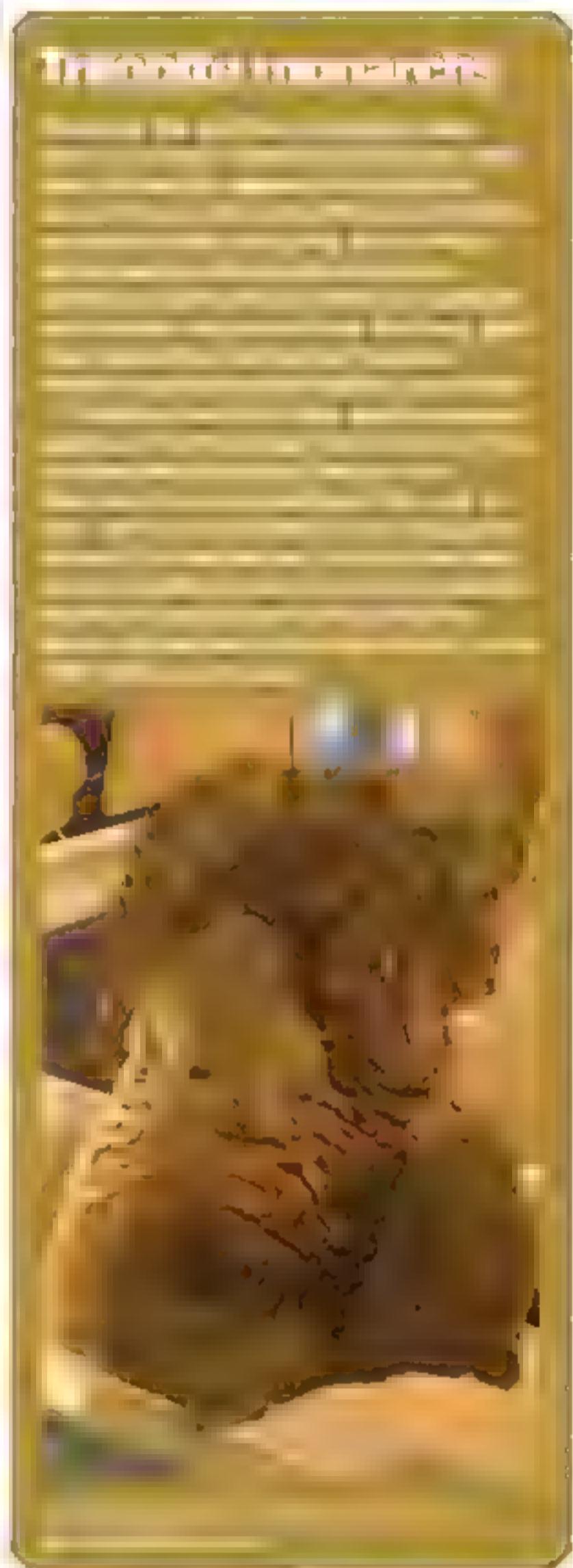
Roaming through Carboniferous marshland and forests, this giant scorpion is commonly referred to as the 'breathing scorpion' due to the evolution of a book lung to breathe air. Much like the pages in a book, a series of plates formed the scorpion's lungs, each richly supplied with blood to exchange oxygen and carbon dioxide.

It's believed that this prehistoric eight-legged predator feasted on the flesh of other arthropods

and small amphibians. In typical scorpion style, *Pulmonoscorpius* was equipped with a mighty sting, also known as a telson. However, without coming face to face with one the potency of its venom will never be known. Using research conducted on modern-day scorpions, scientists have deduced that there is a relationship between pincer size and venom strength – the larger the pincers the weaker the sting, and vice versa. Considering *Pulmonoscorpius* had relatively small pincers for its body size, a sting from this giant scorpion must have packed a serious punch.



Fossils like this show this giant scorpion grew to about the size of an average house cat.



## Immense dragonfly

Today's dragonflies can be hard to spot as they zip above the surface of a lake or pond. However, travelling back to the Permian Period, around 290 million years ago, you would have to duck to dodge a passing dragonfly. Known as *Meganeura*, this genus of giant insect had a wingspan of around 75 centimetres. Much like its comparatively tiny descendants, these winged giants also used tooth mandibles to snap prey from the air. As more and more amphibious species evolved from water, food for these giant carnivores became bountiful. However, like all other megabugs facing the end of this period, climate change claimed the land, destroying *Meganeura*'s habitat and food supply and wiping them from the skies.



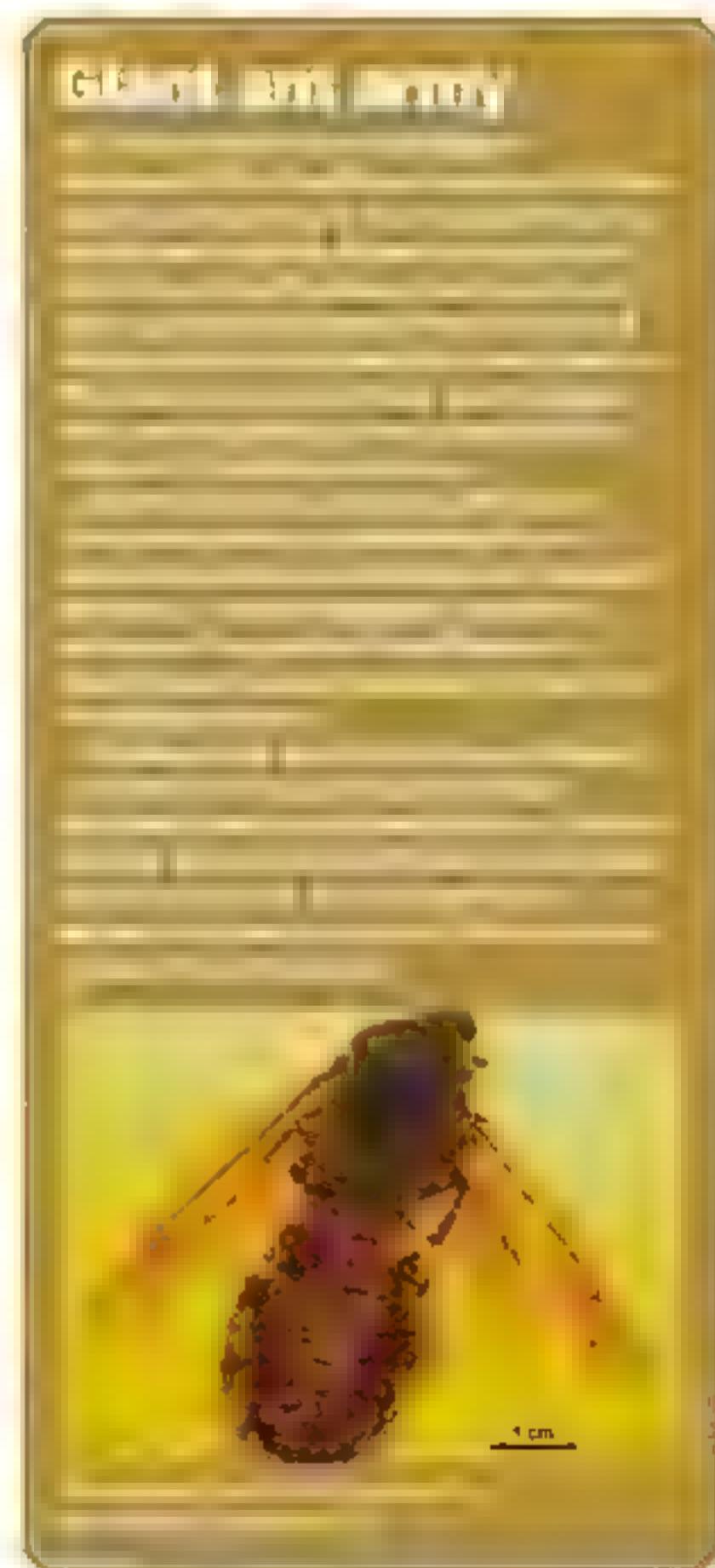
## Living giants

Although not a member of the arthropod family, *Campanile giganteum* is a prehistoric creeper that once crawled across ocean floors. With a shell stretching over one metre long, this massive snail was one of the largest gastropods of its kind. *Campanile giganteum* lived in the Eocene Epoch, 56–33.9 million years ago.

Unlike the mega arthropods, the descendants of these giant snails have maintained a significant size to the present day. Found in Australia's southwest shallows, *Campanile symbolicum* is reminiscent of its ancestor, sporting a conical shell between six and 24 centimetres long.

It's unclear how this giant snail's body appeared, as soft tissue is rarely able to fossilise

"This genus of giant insect had a wingspan of around 75cm"

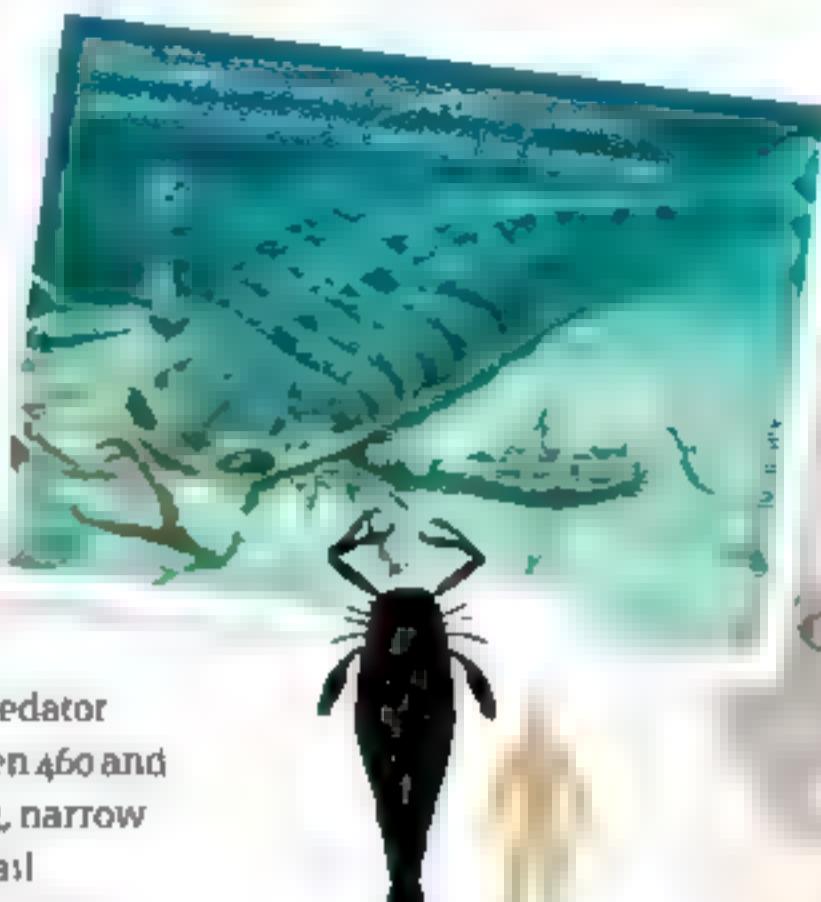


## Sea scorpions

It's understood that the world's arthropods once dwelled exclusively beneath the waves – including scorpions. Before the giant *Pulmonoscorpius* roamed the forest, its ancestors scoured riverbeds in search of food.

Commonly called 'sea scorpions', *Jaekelopterus* was a giant marine predator during the Devonian Period, between 460 and 255 million years ago. It sported long, narrow claws, a flat, shrimp-like body and tail.

In 2007 researchers uncovered one of the *Jaekelopterus*'s fossilised claws, which measured 46 centimetres, and led them to believe that the sea scorpions were around 2.5 metres in length. To support such a body, *Jaekelopterus*'s meal portion sizes had to match. As it became difficult to compete for food against the increasing number of vertebrate species in the waters, over time these giants evolved into smaller species.



The giant claws of this sea scorpion hint at its enormous original size

## Around the world

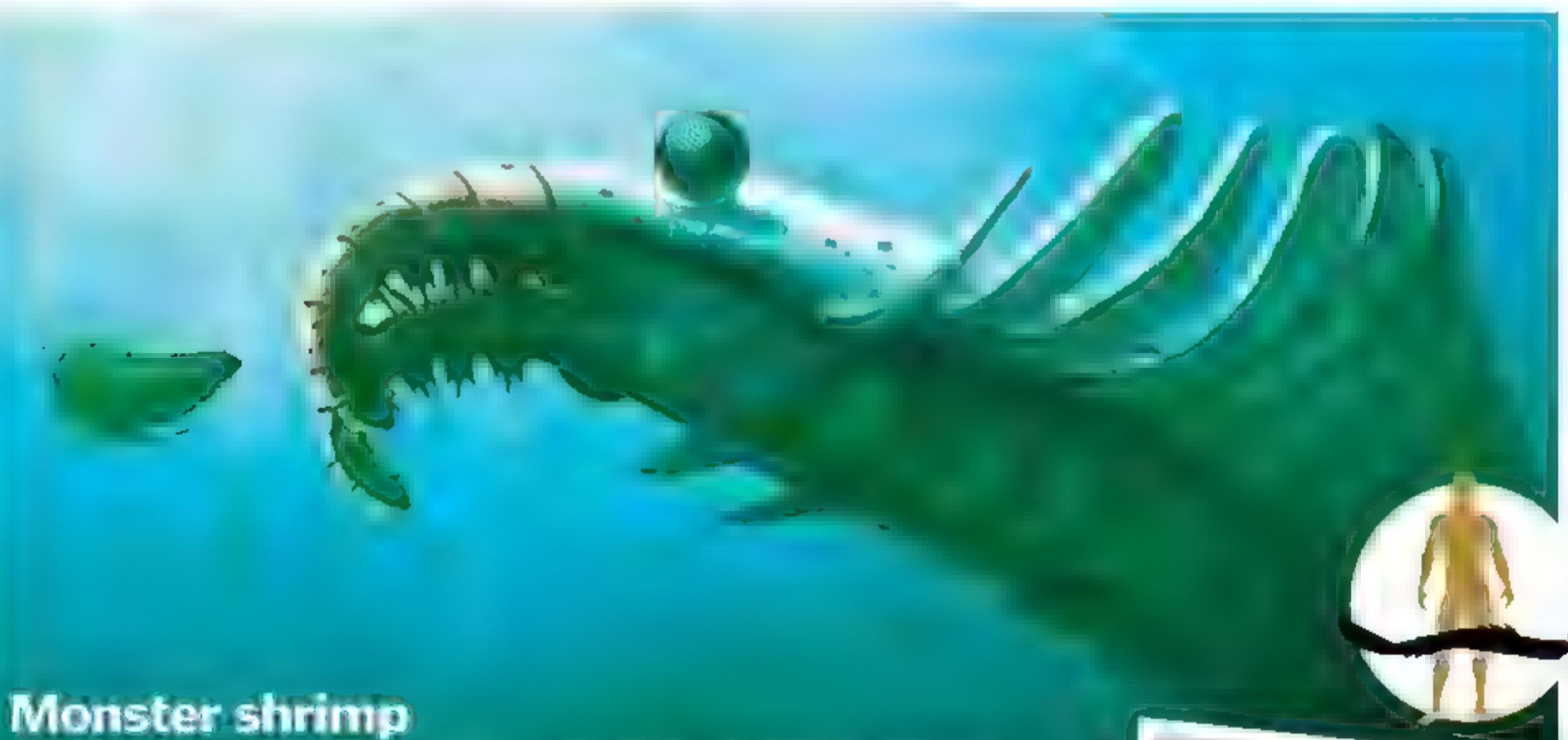
**1. *Jaekelopterus***  
Scotland and east coast of North America

**2. *Palaeoscorpius***  
Scotland

**3. *Merostomata***  
Western Europe

**4. *Jaekelopterus***  
Germany

**5. *Anomalocaris***  
Australia, Canada, China and the US



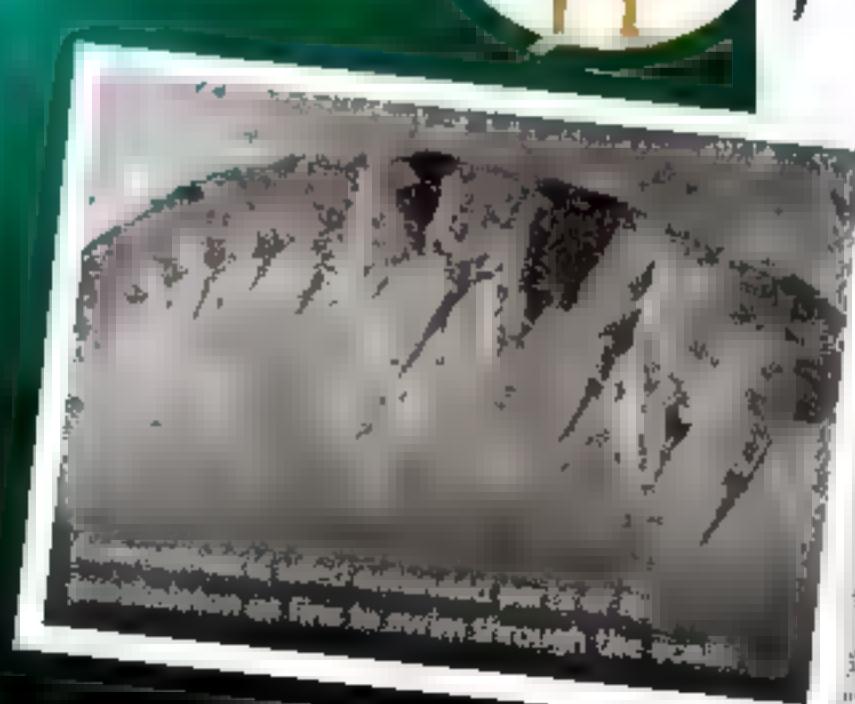
## Monster shrimp

*Anomalocaris* was another giant-sized arthropod that swam through the seas, not long before the time of the sea scorpion. Resembling more of a modern-day shrimp, it grew to around 1.8 metres in length.

Although armed with two toothed and armoured mandibles, it is unclear whether or not they were used for tearing apart the hard shells of passing Trilobites or simply as a way to manoeuvre food into its mouth. Computer modelling of fossil remains suggests that the

pineapple-ring-shaped mouth of *Anomalocaris* would have been unable to close fully and was thus unable to break apart hard material such as exoskeletons, leading many to believe that these marine creatures could only digest soft foods such as worms.

Swimming the seas during the Cambrian Period, around 500 million years ago, *Anomalocaris* moved by undulating its segmented body and extending swimming flaps, which were also the location of gills.



## 5 Facts About

### 1 Preventing interference

Phones are prohibited on the Jodrell Bank site due to the sensitivity of the Lovell Telescope. Even the staff room microwave is shut away inside a metal box.

### 2 Jodrell Bank on TV

The site has appeared in programs such as *Hitchhiker's Guide To The Galaxy* and a 1981 episode of *Doctor Who*.

### 3 An 'unsung landmark'

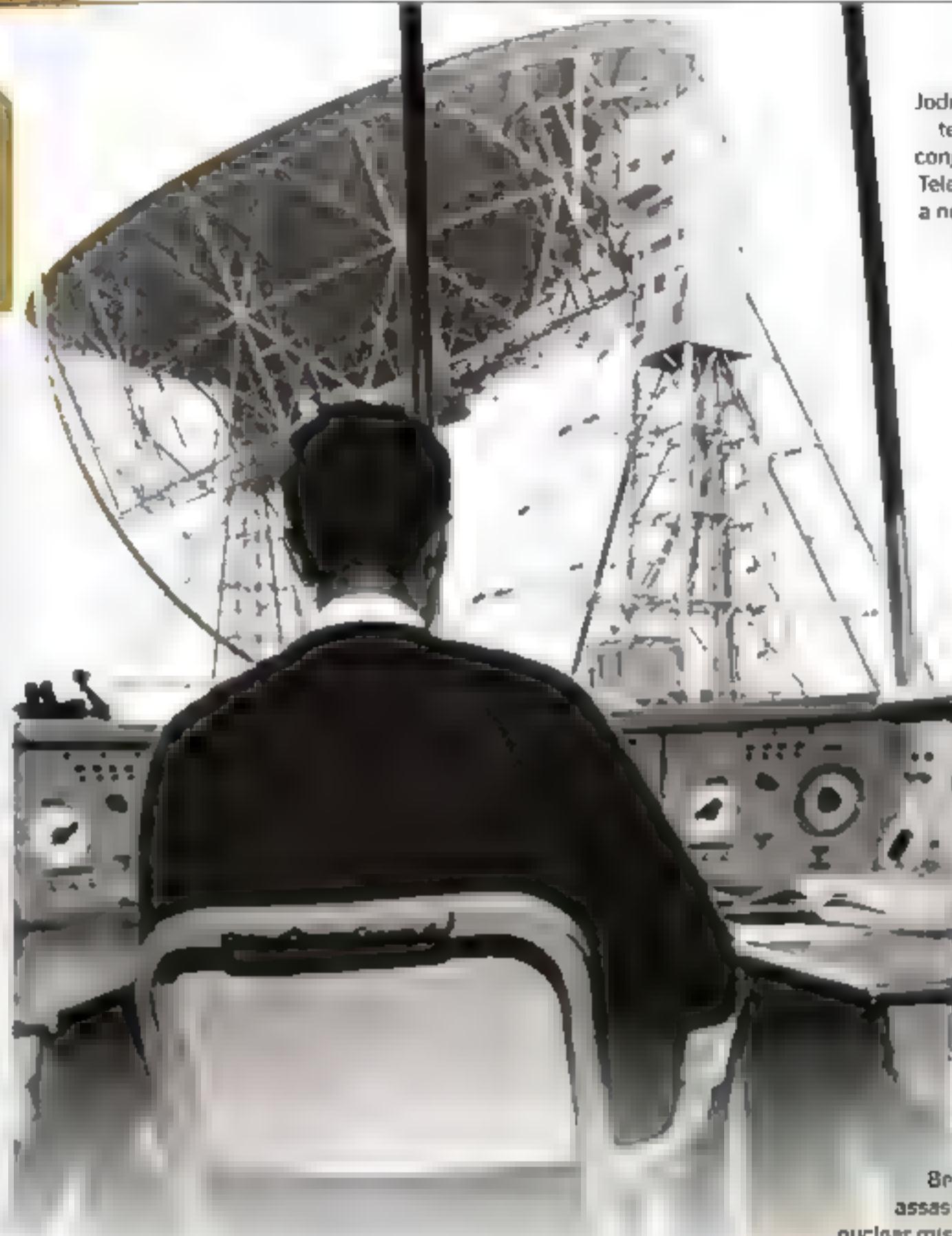
The Lovell Telescope won the 'unsung landmark' competition, held by the BBC in 2006.

### 4 Becoming bigger and better

In 2001 its power was strengthened to give it a fourfold increase in resolution power.

### 5 Made from battleships

Parts of WWI battleships were used when building the Lovell Telescope. HMS Revenge and HMS Royal Sovereign became part of the telescope's altitude rotator bearings.



Jodrell Bank's Mark 1 radio telescope was used in conjunction with the Lovell Telescope to help pinpoint a new class of space time warping objects



Bernard Lovell said that the Soviets tried to assassinate him in 1963 for helping to create a nuclear missile early warning system at Jodrell Bank

# The world's first radio telescope

How Jodrell Bank Observatory was used to prove Einstein's theories and even spy on the Russians

**S**ited 30 kilometres south of Manchester, England, is a site dedicated to exploring the depths of space and enabling us to comprehend what lies beyond our planet. Home to four active radio telescopes, Jodrell Bank is owned by the University of Manchester and is best known for being the site of the Lovell Telescope.

This telescope is named after astronomer Bernard Lovell, who founded Jodrell Bank in 1945. Lovell discovered the quiet site, away from any radio interference, while looking for the perfect spot to study cosmic rays.

One of its first findings was in December 1945. Lovell's team detected echoes, not from cosmic rays but from shooting stars. This led to the discovery that meteor trails leave behind dust particles from comets orbiting the Sun.

Further use for the observatory came during times of international tension, when keeping tabs on what was going on in the sky had added value. Throughout the Cold War, Jodrell Bank was involved in tracking US attempts to overtake the Russians in the space race.

Since that early discovery, hundreds of scientists and engineers have worked in Jodrell Bank. Its extensive findings include discovering gravitational lenses. This new class of space object showed the warping of space-time around them, proving the theories of Albert Einstein over half a century before.

Today, the observatory is a leading radio astronomy facility and recently gained world heritage status on 7 July 2019, highlighting its importance in assisting our understanding of the universe.



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Enter online at [howitworksdaily.com](http://howitworksdaily.com) and one lucky winner will win!

Terms and Conditions: Competition closes at 00:00 GMT on 2nd October 2019. By taking part in this competition you agree to be bound by these terms and conditions and the Competition Rules. [www.futurets.com](http://www.futurets.com). Entries must be received by 00:00GMT on 02/10/2019. Open to all UK residents aged 18 years or over. The winner will be drawn at random from all valid entries received, and shall be notified by email or telephone. The prize is non-transferable and non-refundable. There is no cash alternative.

# BRAIN DUMP

Because enquiring minds  
need to know

## MEET THE EXPERTS



JODIE TYLEY



TOM LEAN



Laura Mears



JAMES HORTON



JO STASS

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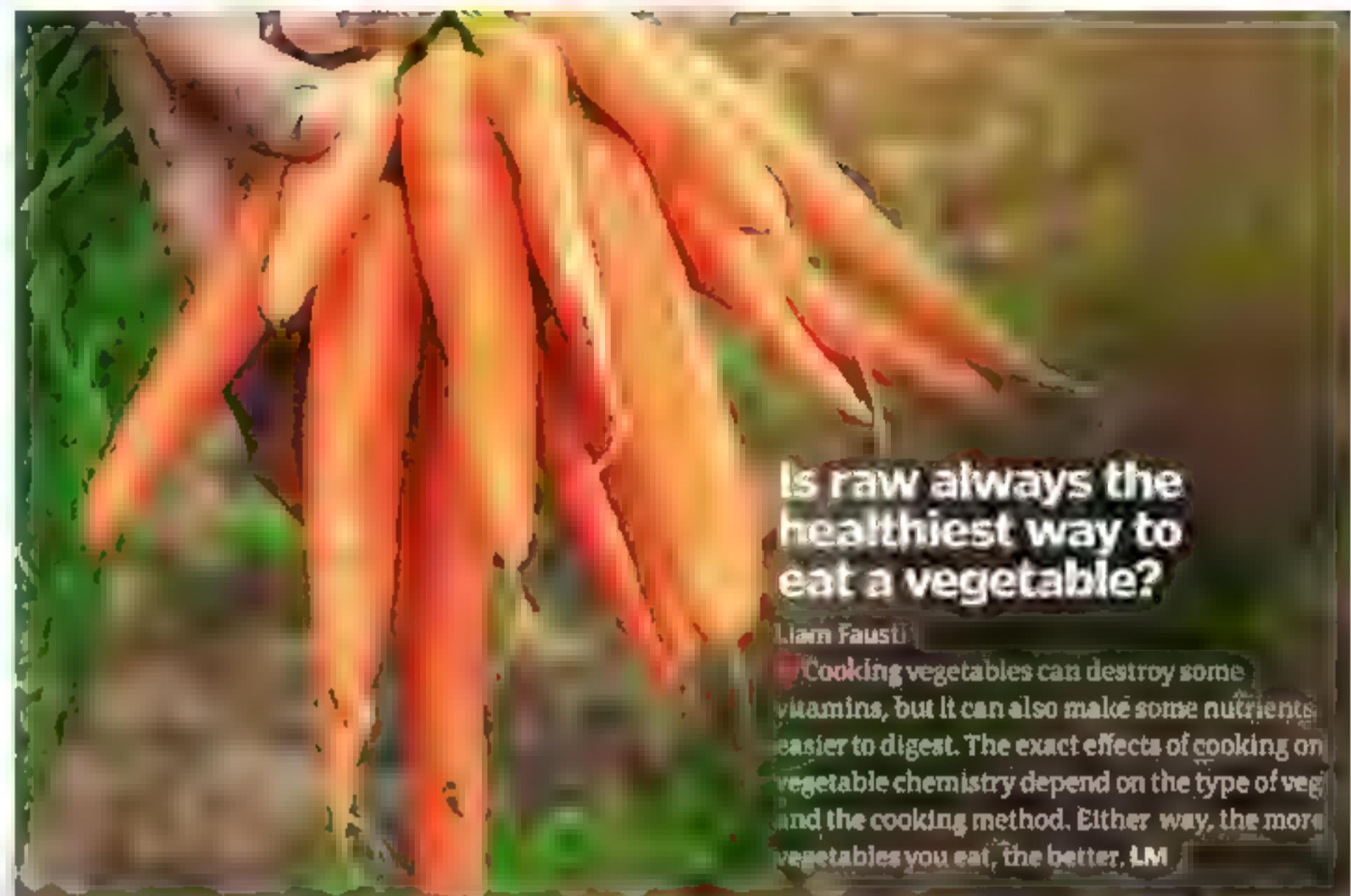
## Could we make an artificial black hole?

Katie McClelland

■ Black holes have gravity that's so intense, nothing can escape their grip. They can trap even the fastest particles – photons of light. In theory, it's possible to make mini black holes by causing high-energy particle collisions inside the Large Hadron Collider, but it hasn't happened yet.

Scientists elsewhere have been busy making artificial black holes to try and understand the real thing. Instead of using intense gravity, these artificial black holes use fibre optics and metamaterials to slow light down. The researchers hope that this might help us to work out what really happens at the event horizon. LM

The 'event horizon' is the border of a black hole. Once you cross, there's no turning back



## Is raw always the healthiest way to eat a vegetable?

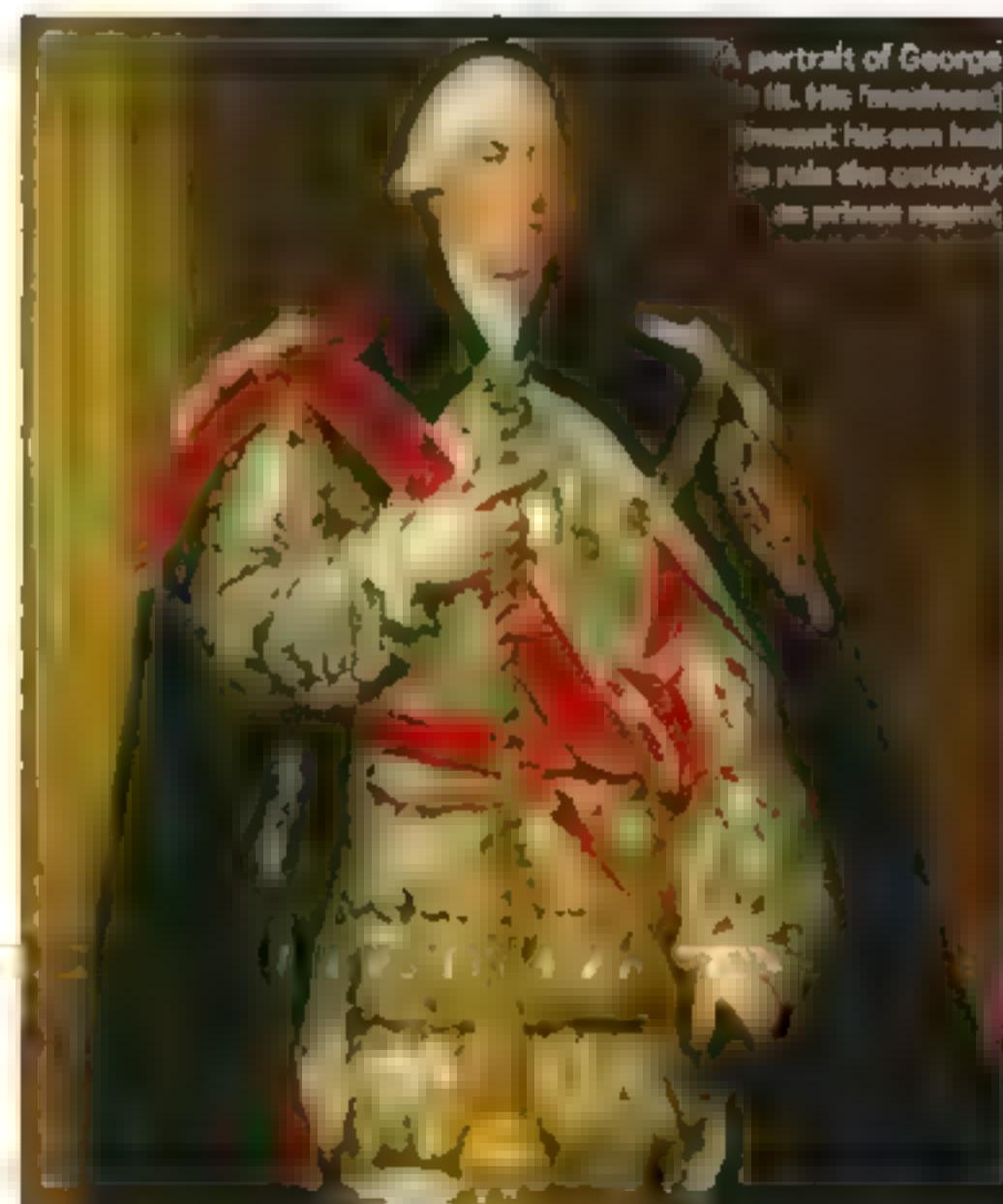
Liam Faust

Cooking vegetables can destroy some vitamins, but it can also make some nutrients easier to digest. The exact effects of cooking on vegetable chemistry depend on the type of veg and the cooking method. Either way, the more vegetables you eat, the better. LM

## Why was King George III 'mad'?

Theo Anderson

In his later life George III suffered bouts of 'madness'. The symptoms included hallucinations, convulsions, mental distress and babbling until he foamed at the mouth. For years, historians have blamed his symptoms on a blood disorder called porphyria, and the problem was perhaps made worse by the presence of arsenic in the medicine he was given. But recent research suggests he may have suffered from a mental illness like bipolar disorder, made worse by his poor general health. TL



A portrait of George III. His 'madness' is thought to have been caused by his own health problems, as well as the fact that he had to rule the country in his son's absence.

## Which countries haven't adopted the metric system?

Jonny Sampson

The International System of Units, known as the metric system, is used by almost every country in the world - except for Myanmar, Liberia and the United States. JT



## Does Japan's emperor have much power?

Eric Bauer

Historically there have been times when the emperor of Japan held great power. But since Japan's defeat in World War II, the role has been largely symbolic, with little political power. JS

## Did Native Americans ever make that 'oo-ooo-oo' sound like in the movies?

Anastasia Vroom

■ Films often misrepresent Native American people and their cultures. Though war cries existed in some tribes, depictions in films are often inaccurate and stereotyped. Having said

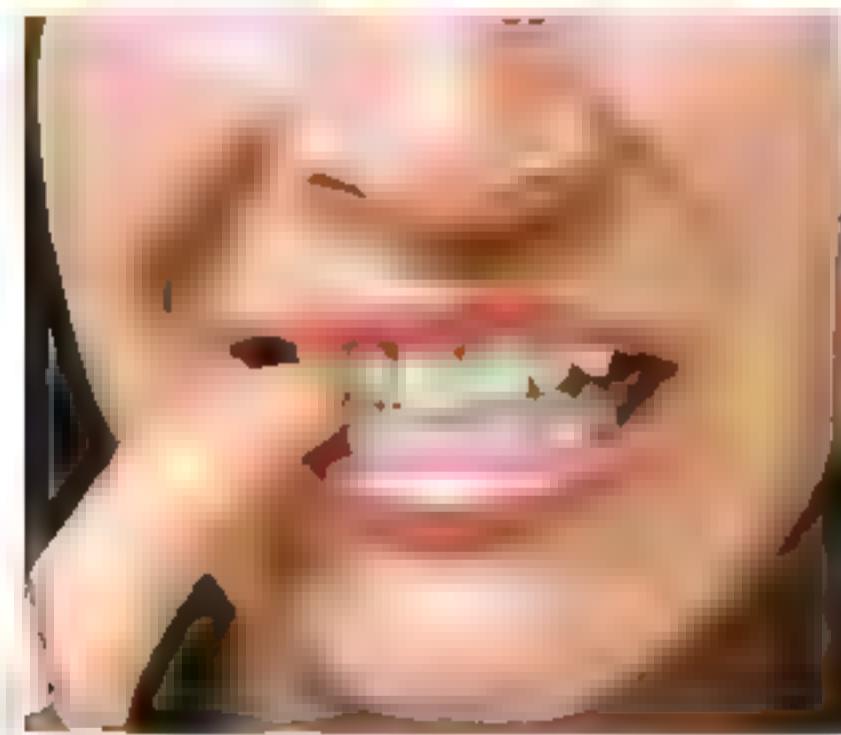
that, the Cherokee and Apache had war cries they would deploy to terrify their enemies, and you can still hear them played out in Native American reservations today **LM**



### What is the most expensive coin in the world?

Jay Wheelock

■ The first dollar to be minted in the US, the 1794 Flowing Hair Silver Dollar, has a value of over \$10 million (about £7 million). Experts believe it was the first dollar ever to be struck, meaning that President George Washington would have inspected it personally **JW**



### Why can't I stop biting my nails?

Beata Jones

■ Scientists have many ideas about why people bite their nails, such as a way of dealing with anxiety, stress or boredom. However, there is no conclusive answer, meaning it probably has varied causes. **TL**



### Why is the universe so big?

Susanna Rey

■ It's generally thought that the universe is roughly 93 billion lightyears in diameter. However, the universe is expanding, and because astronomers have different ideas of how fast this happens, it could be far larger. One recent analysis suggests the universe could actually be as much as 7 trillion lightyears across. **TL**



Real-life pirates were probably quite different to how they appear in books and films

## Did pirates really have peglegs and eyepatches?

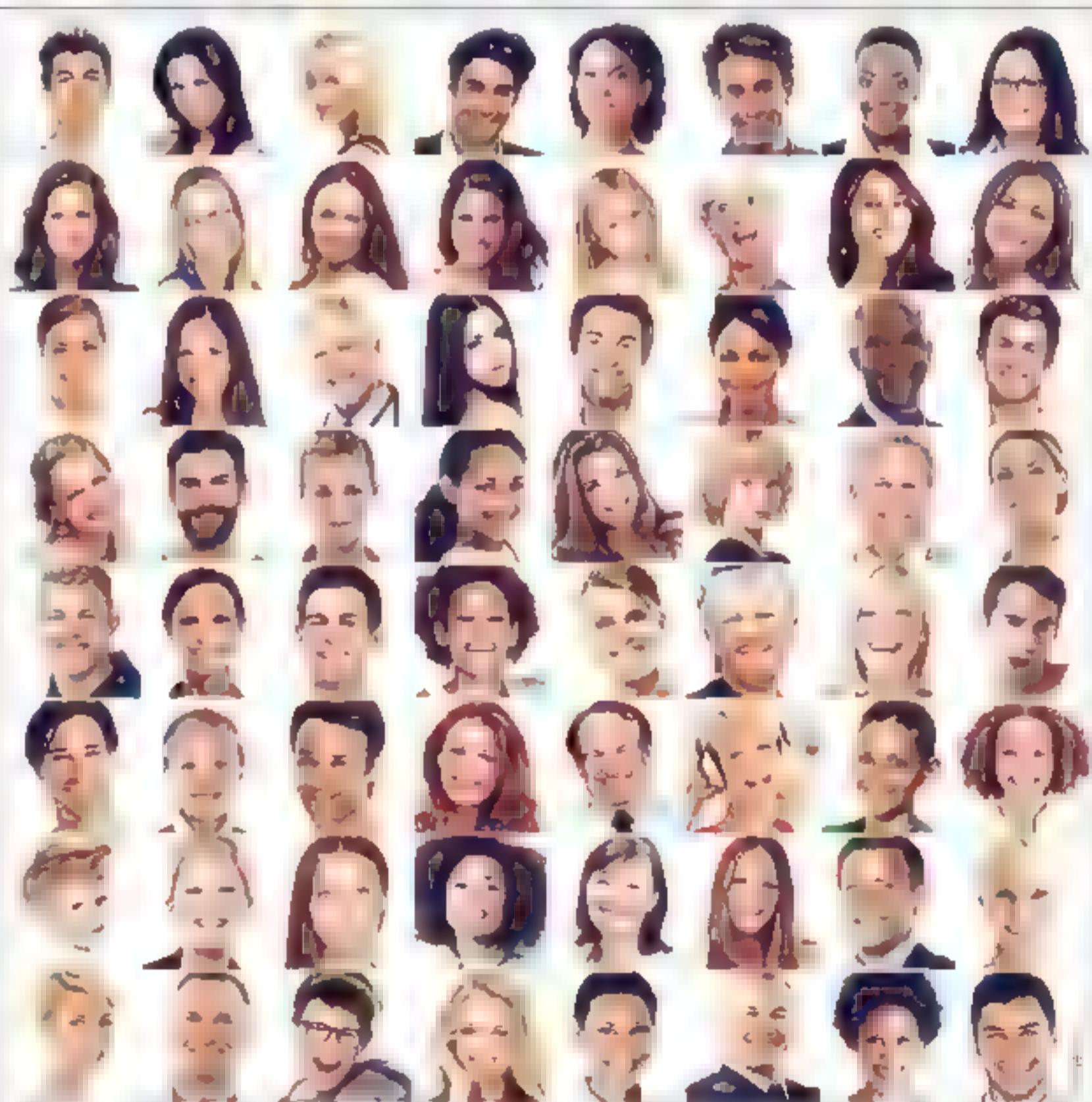
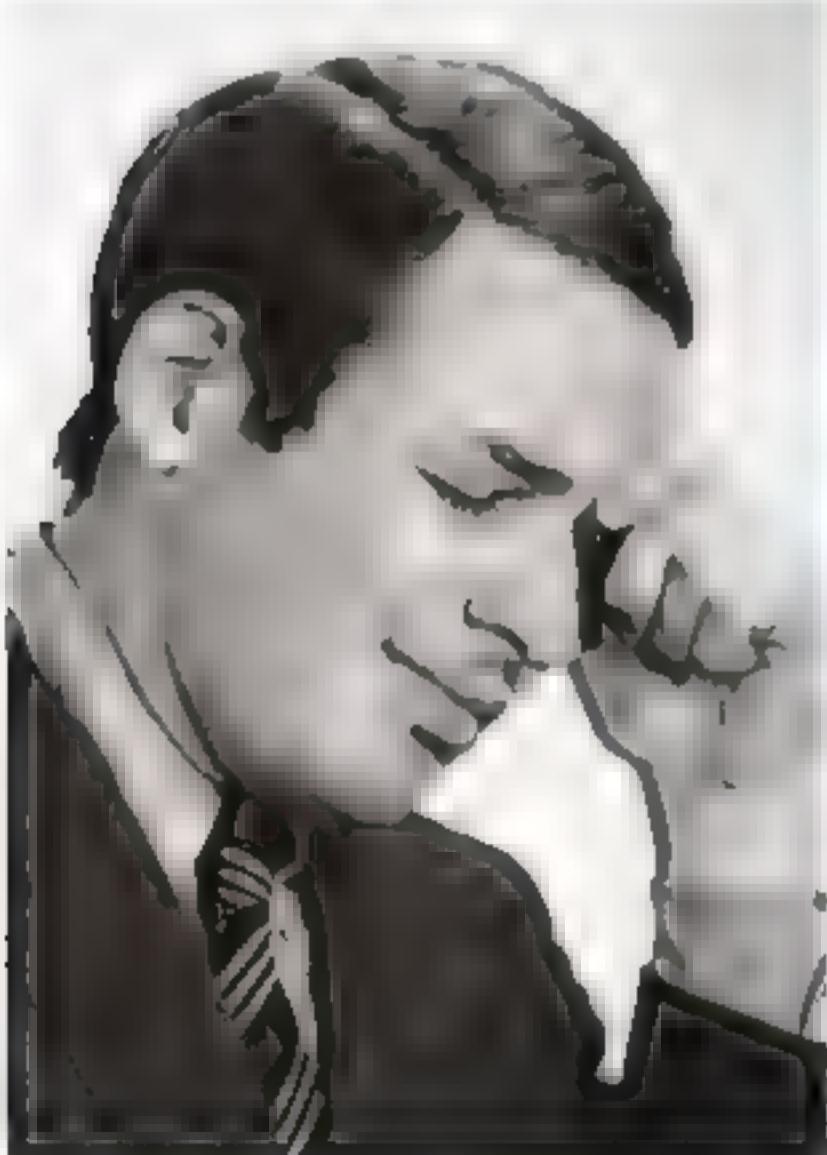
Ben Walsh

■ Pirates' fondness for peglegs and eyepatches has been exaggerated by films and books like *Treasure Island*. It's sometimes said that two-eyed pirates covered one eye with a patch to adjust the eye to see better in the dark, but there is little evidence for this. In the golden age of piracy it's also more likely that a pirate losing a leg would die of infection or blood loss, rather than survive to get a pegleg. Pirate life was brutal, and at least a few pirates used an eyepatch to cover an empty eye socket or had a wooden leg, but they seem uncommon. JS

## Can I hurt my brain by thinking too hard?

Kristine Ng

■ It depends what you mean by hurt. Brains run on a simple sugar called glucose. Neuroscientists have shown that concentrating hard drains glucose from parts of the brain. This makes your brain fatigued, making it harder to concentrate and memorise, at least until the glucose level recovers again. You can also get tension headaches from focussing on a subject too hard, and stress from over-thinking can contribute to a range of health problems. However, as with many other parts of the body, it's often thought that exercising your brain is good for it, improving memory and other cognitive abilities. TL



## What makes a pretty face?

Indra Khatri

■ Research suggests there are many factors for why people find a face attractive. Generally, people prefer faces that are more symmetrical, and seem to favour simpler faces, possibly because they are easier for the brain to

process. Average faces that resemble many others in the population are also favoured, possibly because they hint at a more diverse set of genes. Much of it is also down to personal preference and the life experiences we have had. JS

# BRAIN DUMP

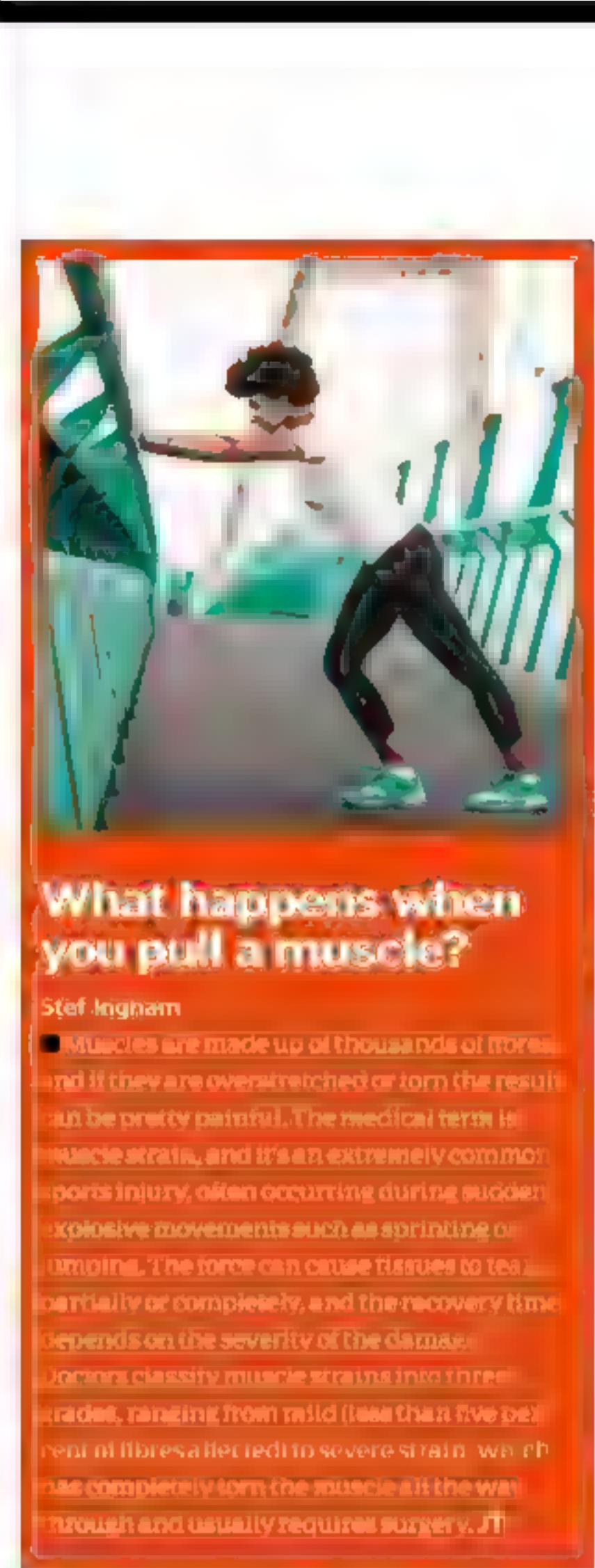


**Why don't loud snorers wake themselves up?**

**Raj Hart**

Electrode studies of the human brain have revealed why loud snorers don't tend to wake themselves up: the brain goes into 'standby mode'. When we fall asleep, the frontal lobes start listening in on incoming noises. This part of the brain controls consciousness and problem solving, and it works like an alarm system. It filters out safe background noises like our own snoring, and only wakes us up if we hear something loud, like a fire alarm or a baby crying. **LM**

Human brains filter out the sounds of their own breathing



**What happens when you pull a muscle?**

**Stef Ingham**

Muscles are made up of thousands of fibres, and if they are overstretched or torn the result can be pretty painful. The medical term is muscle strain, and it's an extremely common sports injury, often occurring during sudden explosive movements such as sprinting or jumping. The force can cause tissues to tear partially or completely, and the recovery time depends on the severity of the damage. Doctors classify muscle strains into three grades, ranging from mild (less than five per cent of fibres affected) to severe strain - when fibres have completely torn the muscle all the way through and usually requires surgery. **JH**



## When will we find alien life?

**Llywelyn Peters**

It's impossible to say if and when we will find alien life. Given the universe's vast size it seems more likely that we will detect aliens long before we meet them, perhaps from their radio transmissions or from analysing the chemicals in the atmosphere of distant planets for any hints of life. **JS**



## What's the deepest point dug by a tunnel-boring vehicle?

**Severine Blois**

The Gotthard Base Tunnel, which runs underneath the Swiss Alps, opened in 2016. It was carved by a tunnel-boring machine that dug down to 2.3km under the mountain surface. **JH**



## Is history always written by the victors?

**Hannah Winstone**

The famous phrase suggests that when two sides clash, the winner writes the history books and portrays themselves in a favourable light. It's certainly not always the case, however. Take the great ancient historian Thucydides - an Athenian - who documented nearly 30 years of war between Athens and Sparta (431–404 BCE), but Sparta won. Or the American Civil War (1861–1865), where there are accounts written by historians from the Confederacy, the losing side. **JH**

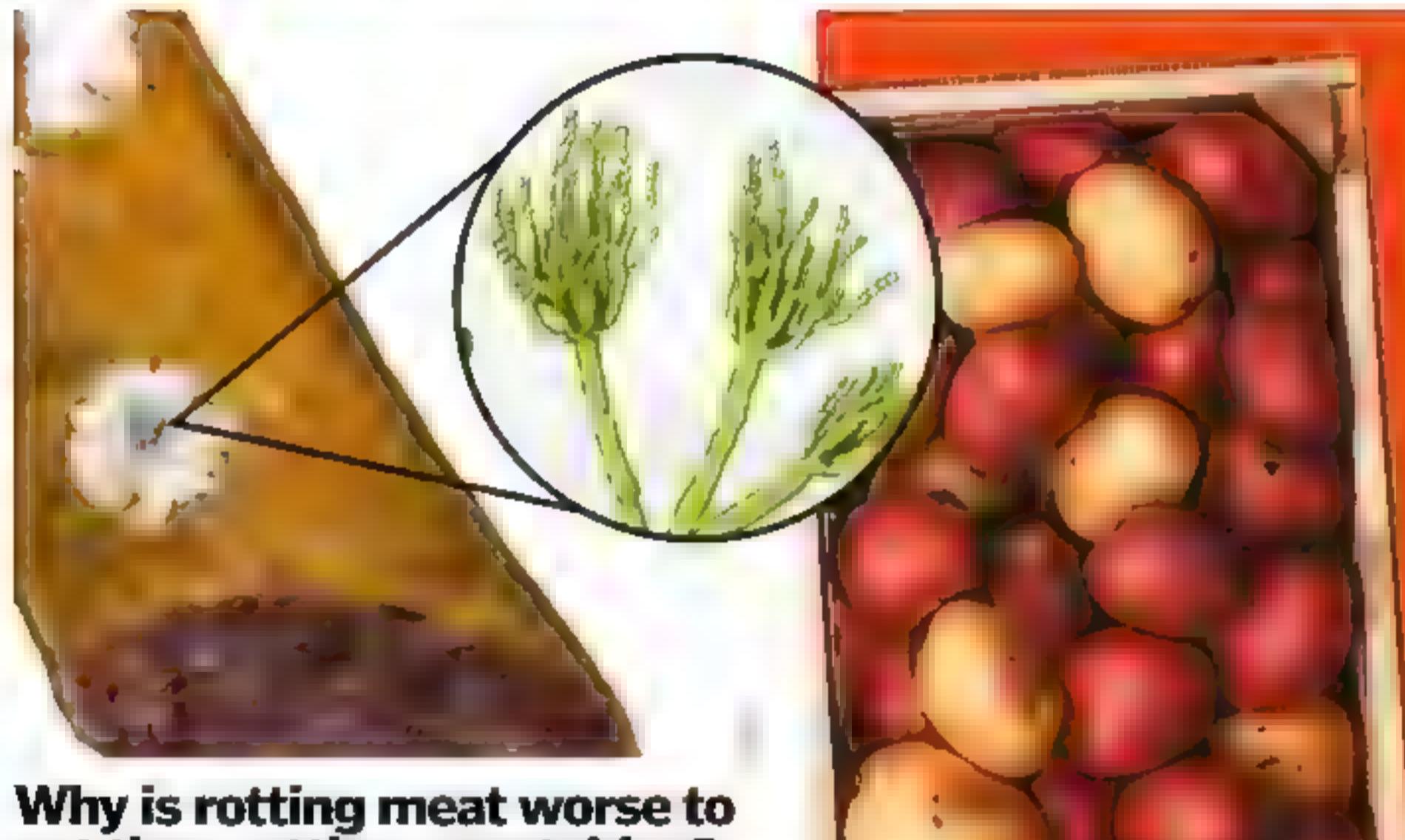


## What is the smallest particle, and why isn't it made of something smaller?

Pauli Crawford

■ John Dalton discovered the atomic theory of structure in the early 1800s. For about a century after this incredible finding, scientists believed atoms to be the most basic building blocks in the universe. However, we now know that every bit of physical matter is made of fundamental particles that compose atoms and everything else. The smallest of these are quarks and leptons, which are too small to accurately measure. But we're not sure if they are also formed of even smaller parts. JH

Current instruments cannot detect anything smaller than quarks and leptons.



## Why is rotting meat worse to eat than rotting vegetables?

Chris Fleming

■ Food spoilage is caused by microorganisms, with fungi and bacteria the most common culprits. Although disgusting, rot-inducing microbes often aren't particularly harmful in either meat or vegetables. However, meat is often thought of as more dangerous. This is because a range of disease-causing food pathogens can reside inside the lymph nodes in meat. JH

## Is there a single food that you can survive on forever?

Nora Rigby

■ Our bodies need a variety of nutrients in order to survive and thrive. These include the major宏量营养素 (carbohydrates, protein, and fat) as well as vitamins and minerals. Unfortunately, we've yet to find a single food that has the right mixture of all the nutrient types to sustain us for the long term. However, a popular choice (one that would be) is potatoes. These tubers are packed with starch—a complex carbohydrate—but also have a fair amount of protein, sweet potatoes also have extra vitamins and minerals. You would need to eat around 20 sweet potatoes a day to get enough calcium and so white potatoes don't get enough protein, so it would not be sustainable. JH

# BOOK REVIEWS

The latest releases for curious minds

## Comet: Photographs From The Rosetta Space Probe

Take a closer look at some of the most incredible space photography ever captured

■ Author: Jean-Pierre Bibring & Hannes Zischler ■ Publisher: Thames & Hudson  
■ Price: £50 (approx \$60) ■ Release: Out now

The exploration of the comet 67P/Churyumov-Gerasimenko was one of the most significant scientific endeavours of the century so far. As the Philae lander touched down on the surface of the comet, it unexpectedly bounced (twice) and ended up near a dark cavity. And after months of sending data back to Earth via Rosetta, the spacecraft that carried the lander, Philae's journey finally ended – its battery unable to recharge due to the lack of sunlight.

But this was only a tiny part of the mission's journey – a fact that this photography-led book goes to pains to make. As we turn the pages we soon see shots of the Earth, Moon and planets including Mars and Saturn. The path that the spacecraft took was incredible, because it used the gravity of these planets to slingshot across the Solar System to get close to Jupiter, where 67P was passing by.

The book starts with a foreword that explains the story from long before Rosetta even saw a launchpad. It's packed with interesting facts about how the mission happened, and how the final team came together from three separate teams working on different solutions. From here, we go on to read about the launch, and then the photos begin.

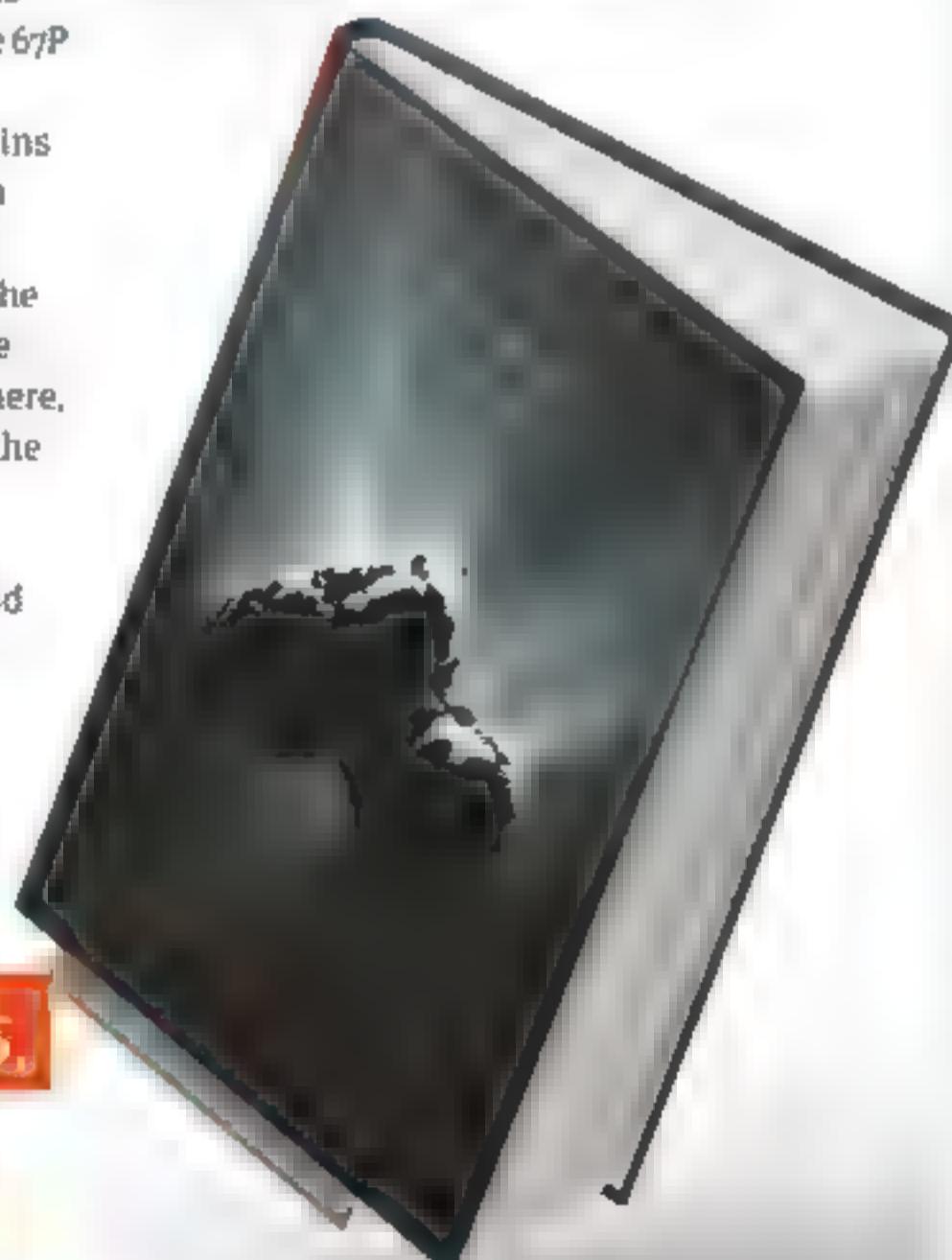
And my goodness, those photos are exceptional. The camera onboard Rosetta and Philae may not have matched the smartphone in your pocket for megapixels, but it had some smart tricks up its sleeve. Which is just as well, because we learn that the comet is as black as charcoal,

and it reflects only six per cent of the light that hits it.

The result is a series of photos that at times we struggled to comprehend: not because they are poorly taken or badly annotated – quite the opposite. Rather, it's because 67P has 1/100,000th of Earth's gravity, and has surface temperatures of -133 degrees Celsius. While the photos and captions paint an incredible picture, there's something so alien about the comet and its surface that it's almost impossible to imagine, even when the photos are in front of you.

This is an expensive book, and one that is probably intended more as a conversation starter than a reference, but it doesn't matter. It's still an exceptional celebration of one of mankind's greatest achievements.

★★★★★



## Super Space Encyclopedia

The furthest frontier

■ Author: Clive Gifford  
■ Publisher: DK  
■ Price: £16.99 / \$24.99  
■ Release: Out now

It hasn't been a bad week for space books – indeed, here's another one for your collection. It's not as unique as *Planetarium*, but DK's tried-and-tested layout is implemented here once again, and they would be fools to change a winning formula, as this book proves.

Taking us through the Solar System one planet at a time, followed by its moons, additional stars and exoplanets, before moving on to the history of space exploration itself, this is nothing if not comprehensive. Insightful annotations accompany the awe-inspiring photography that has become a key hallmark of DK's publications. That pages are devoted to Russian and Chinese ventures rather than solely American ones help to give this book a more rounded feel, and they are a welcome inclusion.

Also present are some surprise inclusions teasing the future of space exploration. Ever heard of the robonaut? You'll get to see one in all its glory – the possibilities it teases are truly remarkable.

By now you'll know exactly what you're getting from a DK book, and that's no bad thing. DK's titles seem almost like old friends, and it's this familiarity and readability that continue to make them sought after.

★★★★★

"And my goodness, those photos are exceptional!"

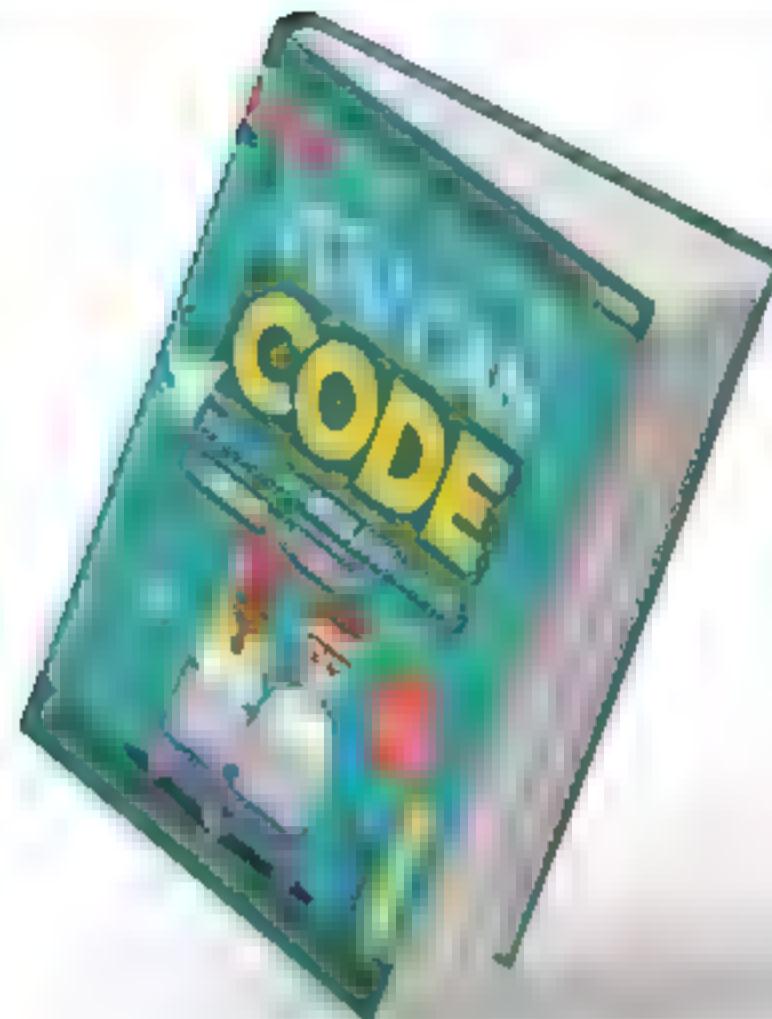
# You Can Code

If you say so

■ Author: Kevin Pettman  
 ■ Publisher: Carlton Kids  
 ■ Price: £8.99 / \$12.95  
 ■ Release: Out now (UK) / 4 February 2020 (US)

You'd be forgiven if the concept of programming code was an alien one to you – you've got to love generational gaps. But it's not as complex as it looks. These days, even children are having coding birthday parties. Those of them who have not had this experience, however, might be advised to check this book out.

Using programming languages Scratch and Python as its basis, this takes its readers on a full beginner's guide into the field of coding, taking them through the process of creating



games, apps, animations and more. If you know how to switch on a computer, then all of this will be readily accessible to you.

The very youngest readers may need a supervising adult on hand for certain aspects of what's included within, but that's to be expected. What we have here is a rock-solid guide to what is both a rather enjoyable pastime and an increasingly important skill in today's job landscape.

★★★★★

# Planetarium: Welcome To The Museum

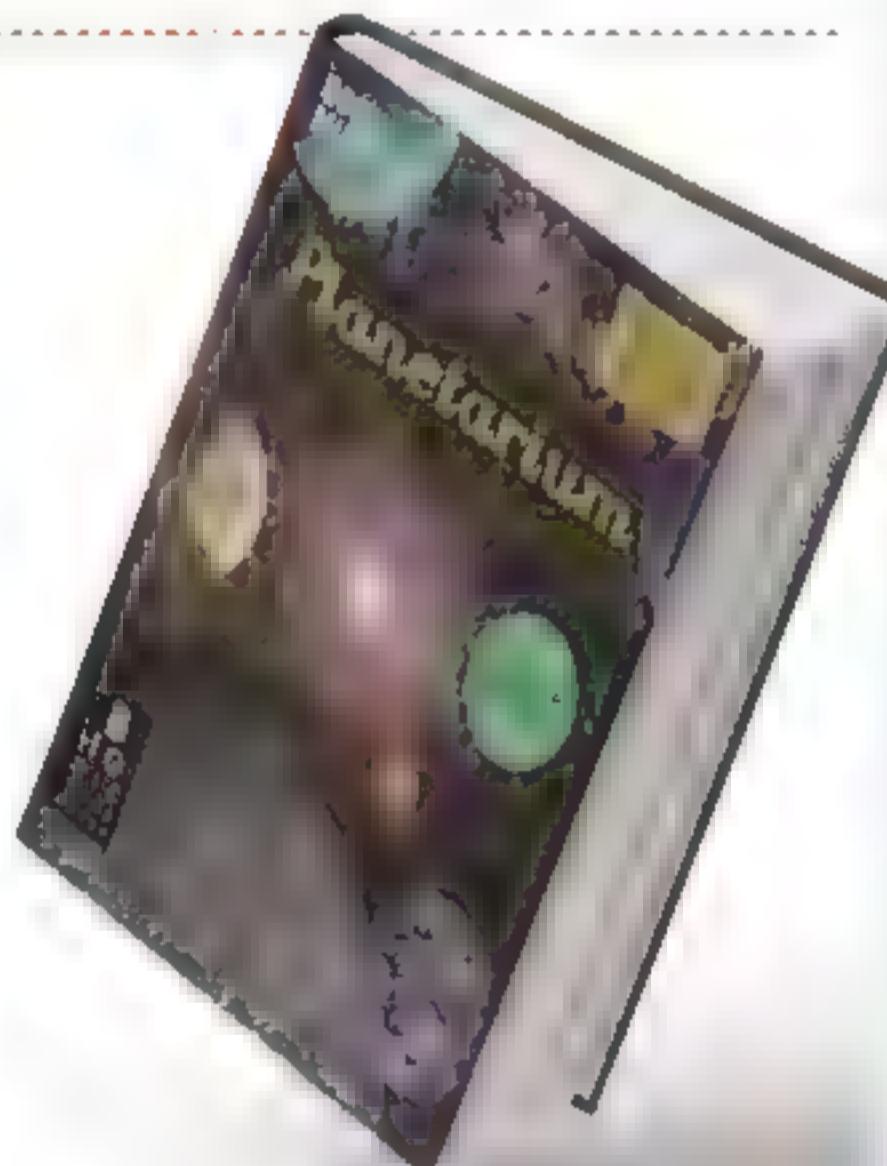
Space in your living room

■ Author: Raman Prinja, Chris Wormell  
 ■ Publisher: Big Picture Press  
 ■ Price: £10.99 (approx \$15)  
 ■ Release: Out now

Taking the form of your very own miniature open-all-hours museum, if the aim was to replicate the sense of wonder that we experience when we set foot in real-life planetariums, then we can report that it's mission accomplished.

This is helped in no small part by the illustrations accompanying this. Technically accurate drawings done in the style of a 19th-century artist illustration, they would look at home in a boutique magazine, and they act as an incentive to turn the pages all by themselves.

But that's not to decry everything that accompanies them. Inevitably, being a junior edition, this doesn't go into quite as much detail as it could. But that's by no means a bad thing. Whether describing the Solar System, the night sky, stars or galaxies, every page contains a perfectly digestible introduction to some sort of phenomena that exists out there.



In fact, we'd go so far as to say that this is the perfect accompaniment for those looking to learn about space and beyond for the first time. Attractive presentation coupled with pitch-perfect prose make this an ideal gift for the budding space enthusiast – and quite possibly for existing ones too.

★★★★★

# DIY Survival Manual: Natural Disasters

Discover the art of earthquake evasion

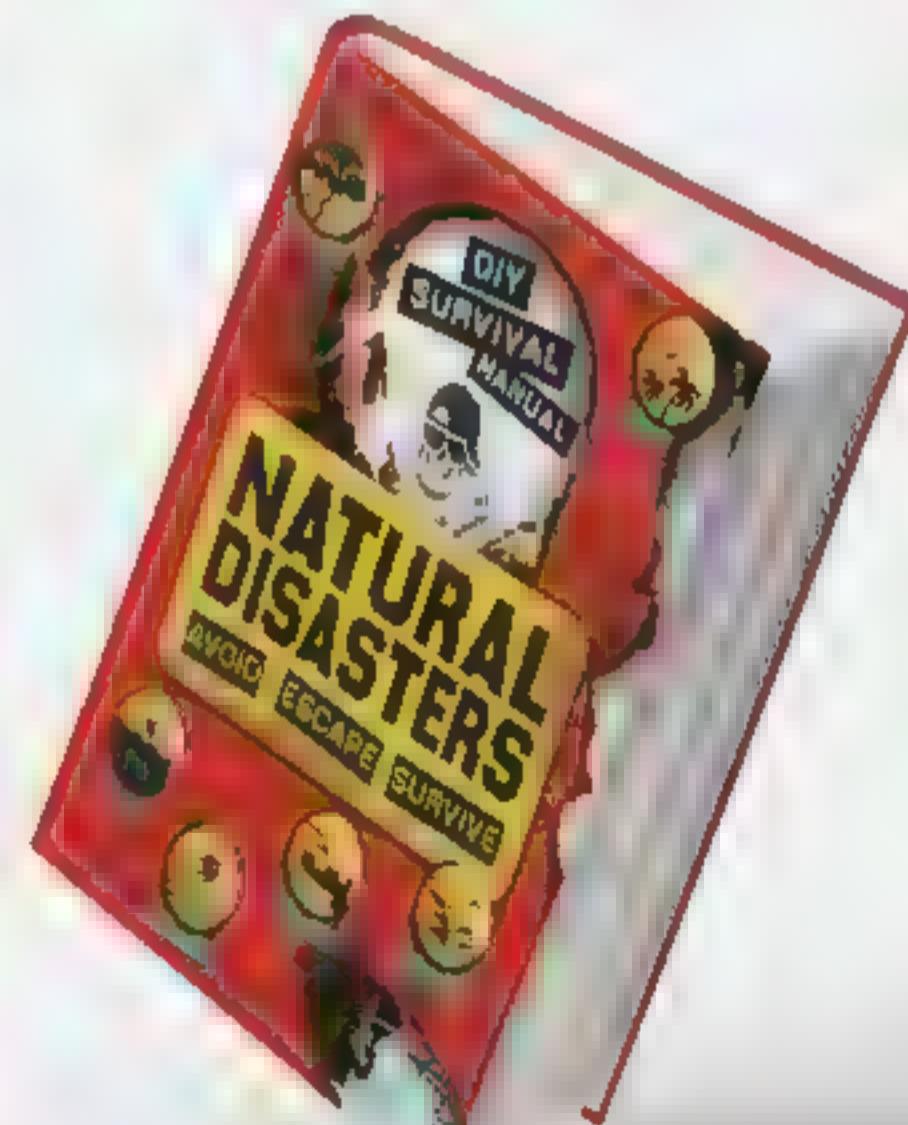
■ Author: Ben Hubbard  
 ■ Publisher: Carlton Kids  
 ■ Price: £8.99 (approx \$10)  
 ■ Release: Out now

Here in the UK, we're in the fortunate position of being relatively safe from the threat posed by natural disasters. We may get the occasional nasty storm or flood, but generally these are small fry compared to what some other countries have to go through.

Although presented in a humorous style, the point being made in this book is a serious one: it aims to arm you with the right know-how when faced by one of these destructive phenomena. Some of this is obvious, like stressing the importance of being prepared and listening to weather warnings, but the rest of it is perhaps not so obvious – we're not going to spoil it and tell you which parts in particular!

Don't go in expecting an in-depth how-to guide – this isn't really equipped with that kind of detail. But it's an interesting diversion for survivalist enthusiasts, at the very least.

★★★★★



# STRATEGY GUIDE

## Carcassonne

Expand and colonise a medieval French kingdom in this competitive land-grab



■ Publisher: Z-Man Games ■ Price: £32.99 / \$34.99 ■ Number of players: 2-5 ■ Recommended age: 7+ ■ Typical game time: 35 minutes

**T**his classic board game involves linking up a jigsaw puzzle of tiles and scoring points according to their placement. Each tile is illustrated with a feature of the Carcassonne landscape - a field, a segment of city, a road or a monastery.

Players take turns to place these tiles, which have to connect so that they make a logical extension of the features on the tiles they face. For example, a road must continue a connecting road, or a segment of city must expand a city it connects to.

Once the player has placed a tile, they have an option of placing one of seven 'meeples' - small wooden followers that allow them to claim a feature, preventing any other player from placing their meeples on the same feature. So a meeple can be placed on a road as long as none of the connecting road tiles have another player's meeple. But two separate features with meeples can be joined by a tile, and in these instances may have more than one meeple on it.

Players score points when they place a tile that completes cities or roads that they have claimed,

at which point they can return their meeple to their pool.

The game ends when all the tiles have been used up. The players with the most meeples on each field or incomplete feature are then awarded extra points. Then the player with the most points wins the game.

## Gallic gameplay

Several key tactics can be a sure path to claiming victory over your opponents

### Prestigious emblems

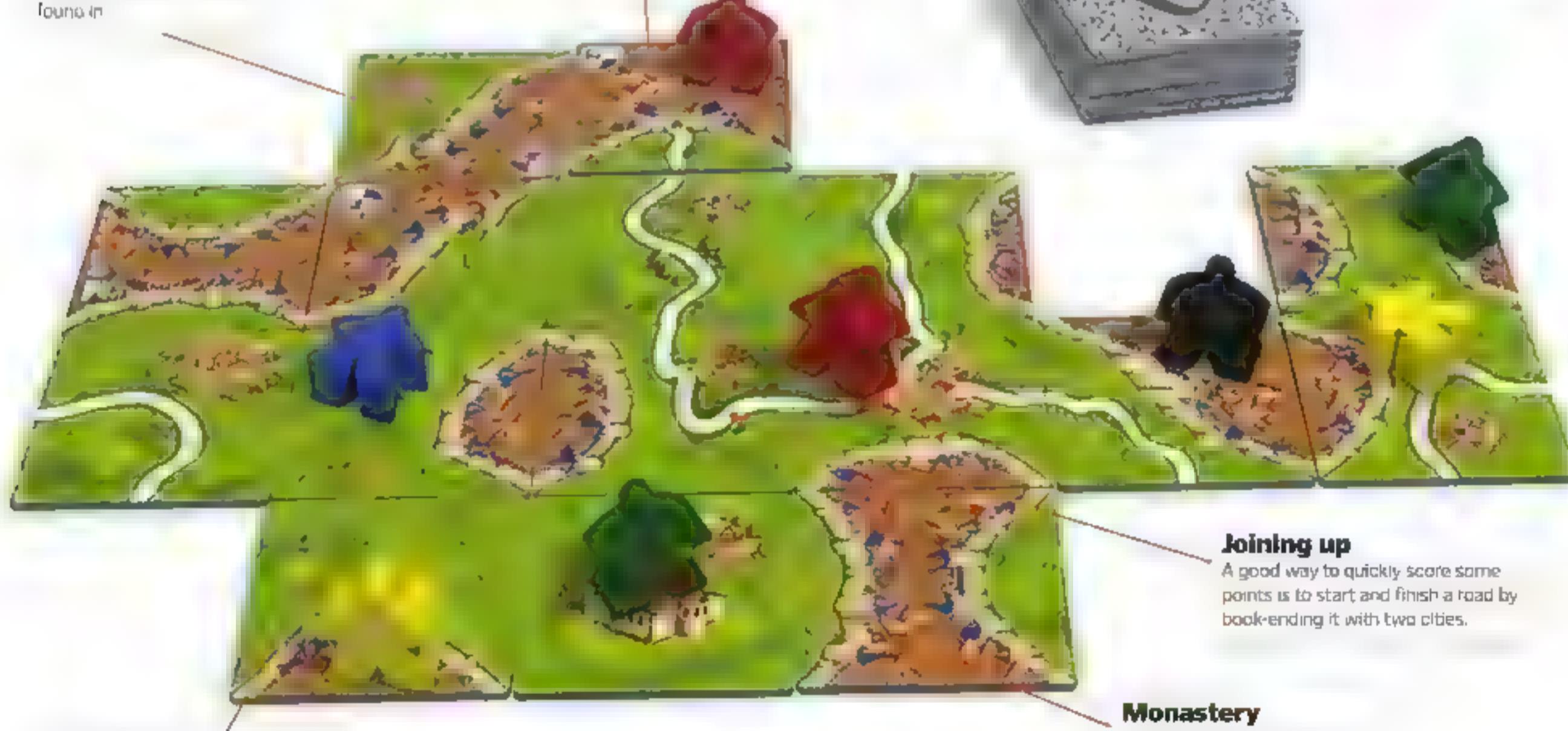
These pennants are worth extra points to the player who claims the city they're found in

### Hijack tactics

Wait until a player has put some work into building a big feature, then join your own small feature to it, in an effort to steal their points

### Meeples

These can be used to score points but also to stop other players from scoring, so don't rush into placing them everywhere



### Feudal fields

A big field can be worth a lot of points, but any meeple placed there stays for the entire game

### Joining up

A good way to quickly score some points is to start and finish a road by book-ending it with two cities.

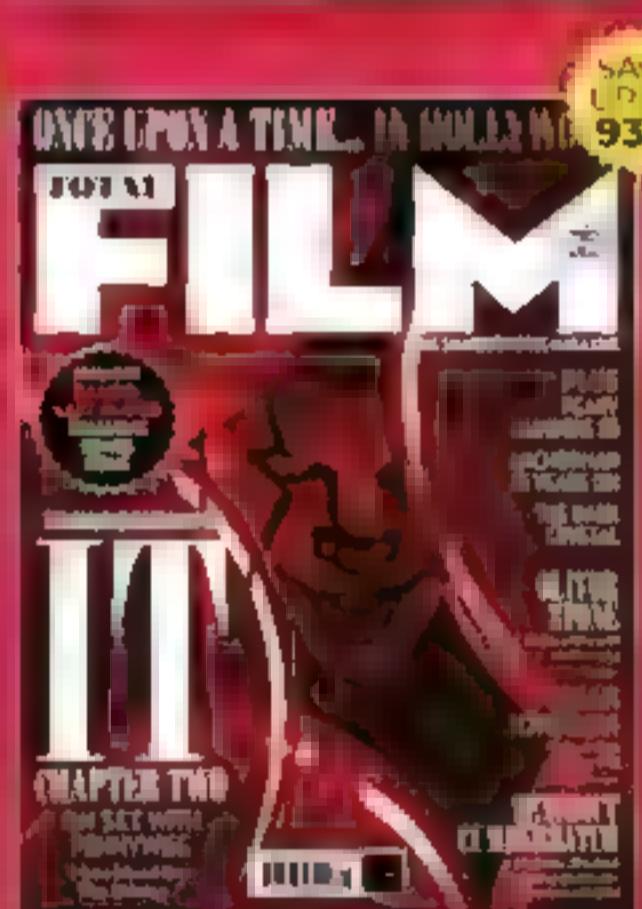
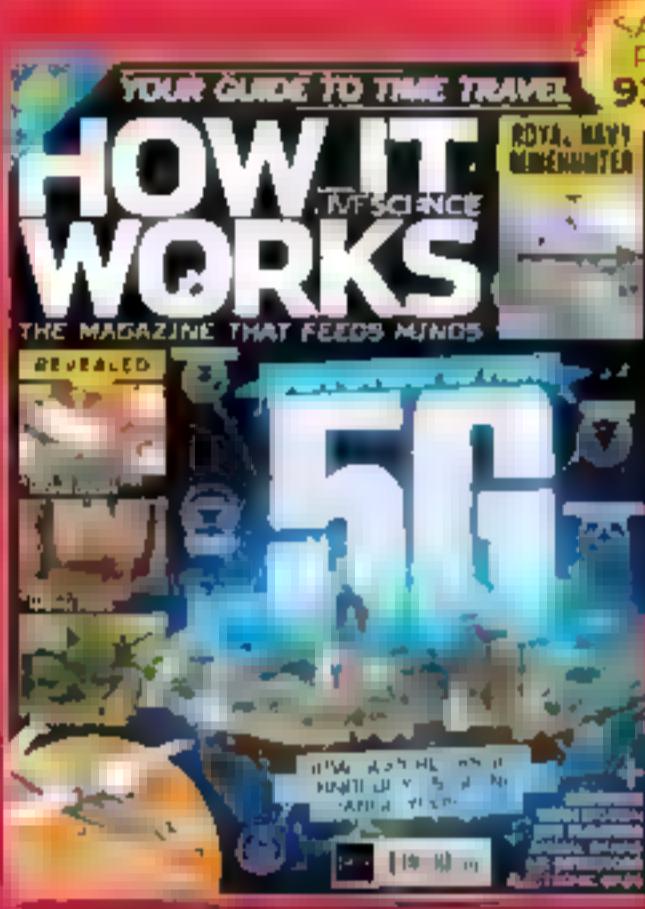
### Monastery

This building scores one point, plus a single point for every tile it's connected to, for a maximum score of 9.

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# BRAINGYM

GIVE YOUR BRAIN A PUZZLE WORKOUT

## Wordsearch



### FIND THE FOLLOWING WORDS...

DATA  
TRANSMISSION  
POLYGRAPH  
EINSTEIN  
EYE  
BLOOD  
COLD  
ENTERPRISE  
PERMAFROST  
MARS  
INSECT  
LOVELL

## Quickfire questions

Q1

Q2

Q3

Q4

## Spot the difference

See if you can find all six changes we've made to the image on the right



# Sudoku

Complete the grid so that each row, column and  $3 \times 3$  box contains the numbers 1 to 9

**EASY**

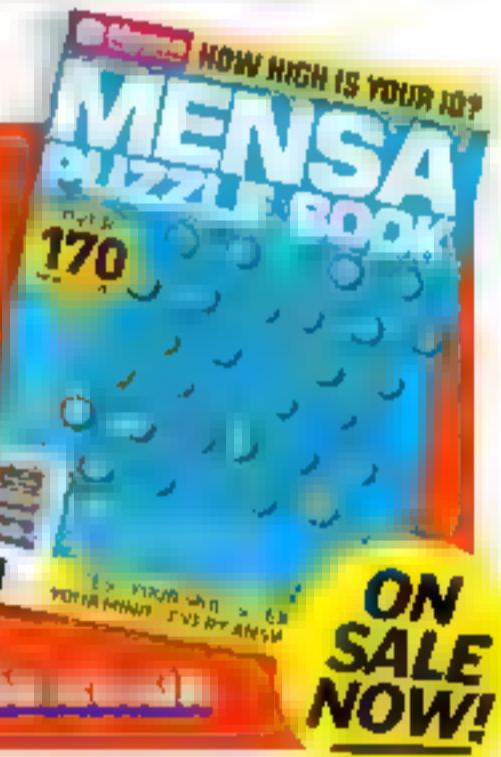
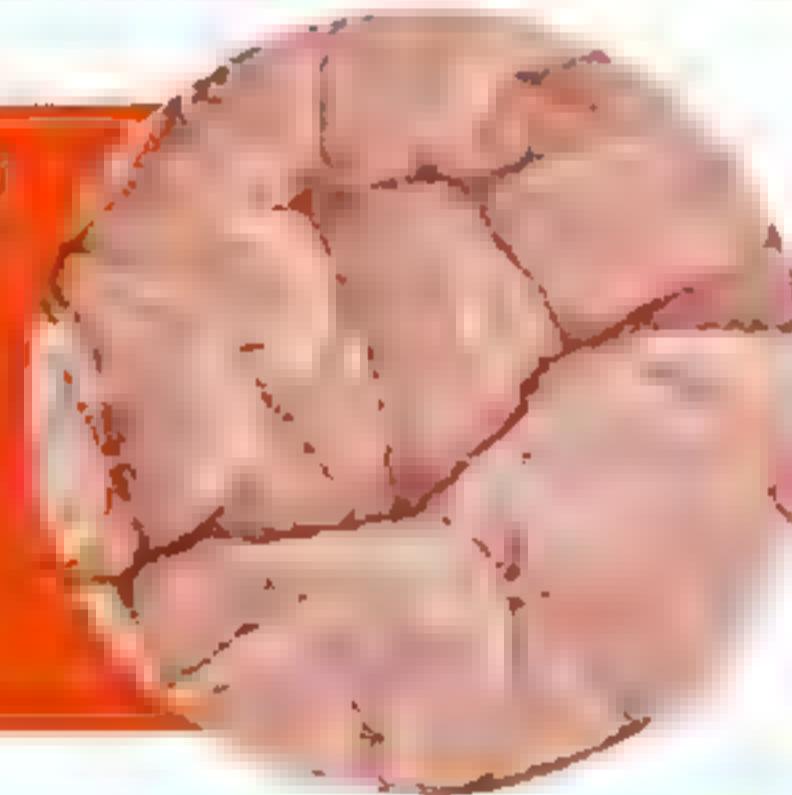
7	3			2	8			
4	5	3	2	9	6	1		
9	2	1	8	5		3	7	
8	4	2	5	7				
9				8	5			
6		8	3		4			
3	9	6	1	2	5			
2	1	8	5	3	9	6	4	
7	6	2	8	3	1			

**DIFFICULT**

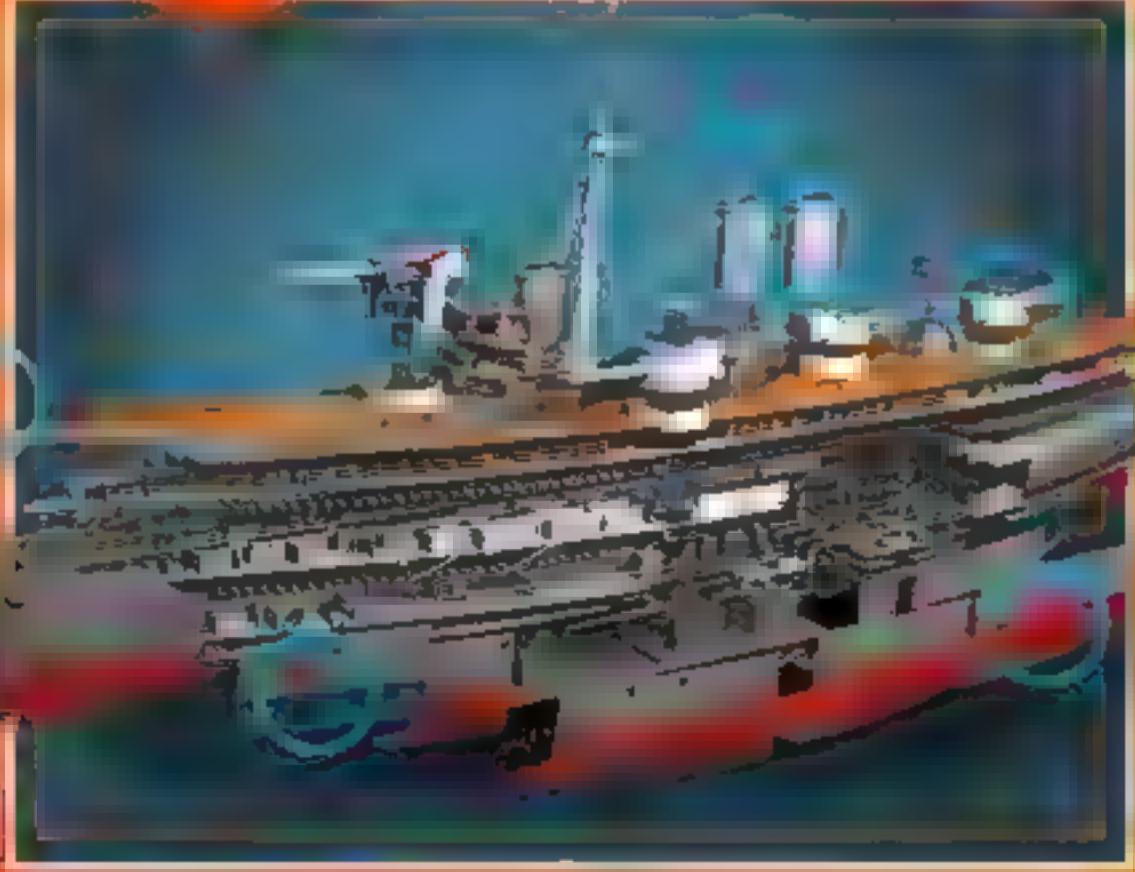
1			2	7				
8	9		7	6	5			
4	3			8	2			
	4		2	1				
6					3			
5			7					
8			6		7	4		
7					1	6		

**What Is It?**

**PUZZLES**



**PUZZLES**



**PUZZLES**

Q1  
Q2  
Q3  
Q4



## Get in touch

If you have any questions or comments for us, please send them to:

How It Works magazine @HowItWorksMag howitworks@futurenet.com

The Big Bang is the leading theory for the beginning of the universe.



### Letter of the month

## Before the Big Bang

Dear HIW

Thank you for your articles on the Big Bang. Has mankind any idea where the Big Bang came from and what was there before the Big Bang? How did it come about? Also could mankind accidentally perhaps cause another Big Bang?

Stephen Conn

This is arguably science's most difficult question to answer, because whatever was around before the Big Bang now resides beyond the known 93 billion-light year sphere of the universe that we live in. We can only see as far back as 300,000 years after the time of the Big Bang, but we've calculated that it occurred around 13.8 billion years ago. At the moment of its birth, an expansion of space itself inflated faster than the speed of light, doubling in size 90 times in a tiny fraction of a second. This event is what we now refer to as the Big Bang, and it has been a theory about the origin of the universe since the 1920s.

However, since then a handful of theories from the world's greatest minds have postulated



alternative ideas. This includes the concept of a multiverse, in which our universe has merely broken away from another universe. Others have suggested that the Big Bang was the point at which our universe appeared through the other side of a black hole. But the most commonly accepted theory, and perhaps the bleakest, is that there is nothing beyond our universe and there was nothing before its existence.

Today's physicists are still trying to work out what exactly happened all those billions of years ago. One such way is to recreate a version of the Big Bang on a small scale: using particle accelerators such as the Large Hadron Collider, scientists are attempting to replicate the sub-particle collisions that occurred at the beginning of time to better understand the truth behind our universe.

Scientists at NASA are also developing different telescopes, such as the James Webb Space Telescope (JWST), to look back further towards early-forming galaxies. Planned for launch in 2021, JWST could reveal more about time and space, bettering our understanding of the beginning of everything.

## Washing water

Dear HIW,

How does water get cleaned after going down the sink?

Paul Chappell

Flowing down the plughole, water is sent on a journey through our underground sewage system to get cleaned. From sink to stream, our waste water is exposed to a multitude of cleaning treatments. Firstly water, along with other general sewage, is passed through a series of screens to physically remove solid waste. Then, moving through biological treatments, microorganisms are added to break down any remaining organic matter. In modern treatment plants, this process is furthered by activated sludge treatment, where air is bubbled through the liquid to encourage bacteria growth. Before going back into natural water systems, the filtered water goes through chemical treatments and biological processes, such as reed beds, to remove contaminants that can be harmful to the environment.



Waste water is washed through a series of physical and biological treatments

## Cleaning eyeballs

Dear HIW

I have been wondering this for a while, but why do we blink? Do we do it solely to clean our eyeballs?

Willow Lin

On average humans blink around 15-20 times a minute, with each blink lasting only a tenth of a second. Each speedy shut of the eyelid cleans away dust and dirt before it can cause any damage to the eye. However, blinking isn't solely an exercise in good eyeball hygiene but a way to make sure they stay well lubricated. As the skin passes over the eye lens, it carries with it a mixture of oils and mucus to prevent it from drying out.



## HIW collection

Dear HIW,

We always look forward to the latest edition hitting our doormat! As you can see we are collecting every edition as we often read them again. Our subscription is a gift from our Grandma and think it was wonderful of her. Here is a photo of Ezekiel (aged 12) with lots of his favourite editions. Thank you for keeping us interested and engaged with a wonderful publication.

Ezekiel and Malakai Tejevo



## HOW IT WORKS NEEDS YOU!

To celebrate the 10th anniversary of the magazine, we want you to take inspiration from Ezekiel's photograph and snap a shot of yourself with a copy of How It Works. We'll select some of our favourites to be printed in the next issue.

You can email your photographs to [howitworks@futurenet.com](mailto:howitworks@futurenet.com) or via Twitter (@HowItWorksmag) and Facebook (@HowItWorksMagazine). Photos must be received before 11/09/19 in order to be considered.

[www.howitworksdaily.com](http://www.howitworksdaily.com)

What's happening on...

## social media?



If you could time travel back to any historical moment in time, when and where would you go, and why?

@ian40766

"I'd go back to 2 weeks before my exams and do some revision this time!"

@helenharding83

"I would go to when Elizabeth I gave her speech "I have the heart and mind of a king, and a king of England too" after winning the Spanish armada"

@taitanique

"The sinking of the Titanic. I have been a researcher for many years so would love to know if various theories are correct."

@angiehoggett

"I'd love to go back to the moon landings, there was so much excitement and pride I'd love to witness it."

@pippynh

"I'd go back to be at Woodstock to see Jimi Hendrix play - so iconic and it would have been amazing to have been there!"

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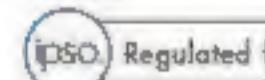
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# FAST FACTS

Amazing trivia to blow your mind

## 5G'S

### BANDWIDTH

IS AROUND 30 MILLION TIMES GREATER THAN AN ANALOGUE TELEPHONE CALL

# 1939

THE YEAR THE FBI BOUGHT LEONARDE KEELER'S LIE DETECTOR FOR USE IN INVESTIGATIONS

PREHISTORIC SPIDER MEGARACHNE HAD A BODY 60CM LONG AND LIVED 300 MILLION YEARS AGO

# 36

THE AGE AT WHICH ALBERT EINSTEIN PRESENTED HIS THEORY OF GENERAL RELATIVITY TO THE WORLD

## -18.1°

### CELSIUS

THE MINIMUM TEMPERATURE THAT ALASKAN WOOD FROGS ARE KNOWN TO SURVIVE, PARTLY FROZEN

# 6

OUT OF THE UK ANTI-DOPING AGENCY'S TEN RULE VIOLATIONS APPLY TO AN ATHLETE'S SUPPORT PERSONNEL AS WELL AS THE ATHLETE

ANTARCTIC SCIENTISTS USE A RFID REMOTE-CONTROLLED PENGUIN TO MONITOR PENGUIN HUDDLES

## 25KPH

THE MAXIMUM CAPABLE SPEED OF AN E-BIKE BEFORE IT NEEDS TO BE LICENSED (UK)

## A TACHYON

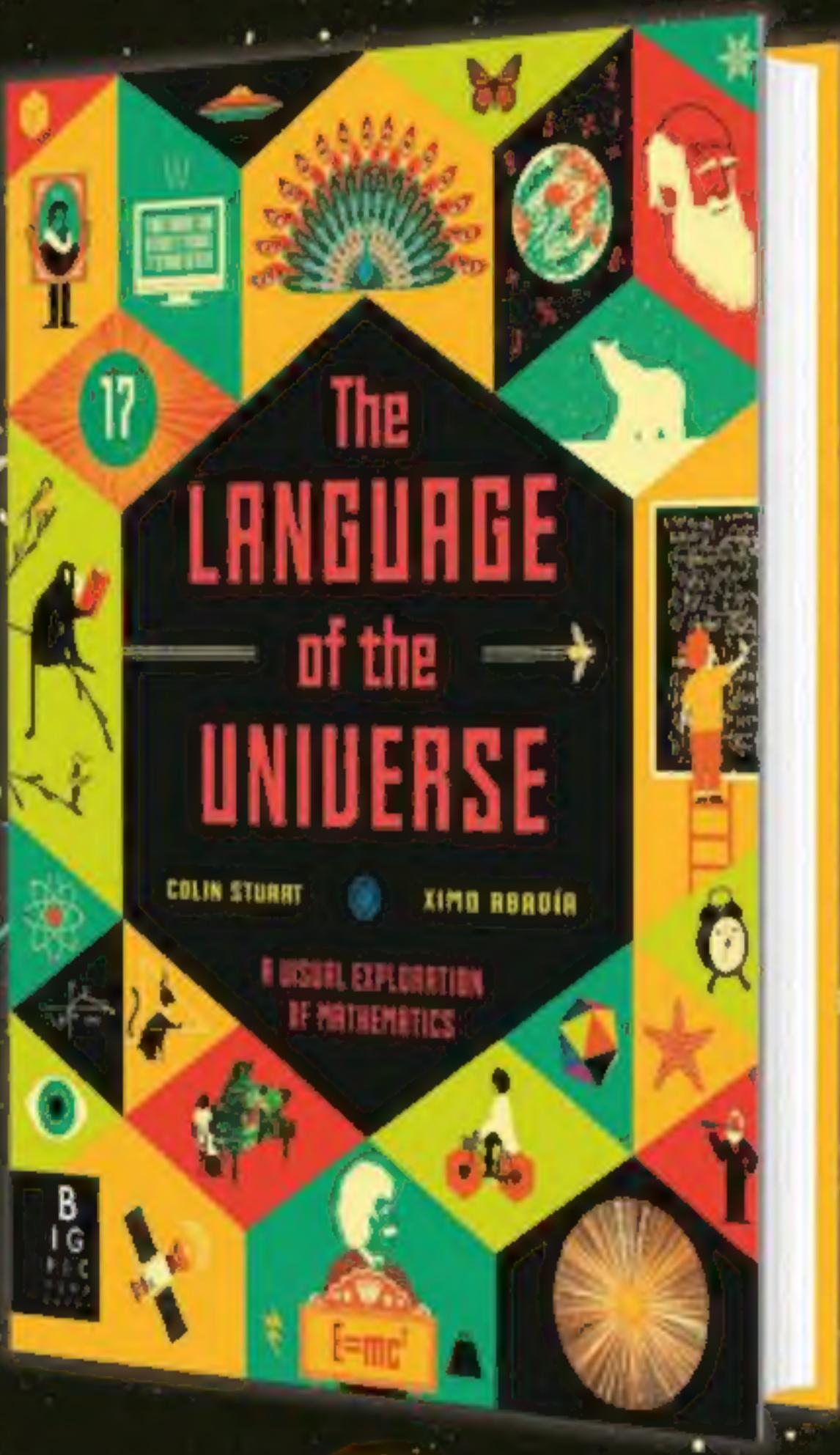
IS A HYPOTHETICAL PARTICLE THAT MOVES FASTER THAN THE SPEED OF LIGHT - BACKWARDS THROUGH TIME

# 1.5 KM

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## MAKE IT PERSONAL

Scalextric ARC Sets allow you to customise your race for a truly personal experience.

Scalextric ARC PRO is a revolutionary digital slot car system that allows users to wirelessly create and manage races with a handheld smart device, such as a smartphone or tablet. Download the ARC app, then connect your smart device via Bluetooth to the new ARC Powerbase, unlocking unique features and control of your Scalextric races.

With Digital capability, race up to 6 cars on any lane and change lanes to cut up your rival and overtake.

Personalise your race by selecting features such as race type, driver names and number of laps. Customise and save your race settings and car setup, before you head out on the track...



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